PB-249 449

MODEL VERIFICATION - AIRCRAFT EMISSIONS IMPACT ON AIR QUALITY

Scott D. Thayer, et al

Geomet, Incorporated

Prepared for:

National Environmental Research Center

September 1974

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PB 249 449

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EPA-650/4-74-049

MODEL VERIFICATION - AIRCRAFT EMISSIONS IMPACT ON AIR QUALITY

by

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Glenn H. Stadsklev, and Billy Don Weaver

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Contract No. 68-02-0665
ROAP No. 21ADO
Program Element No. 1AA009

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Prepared for

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

September 1974

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This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
Model Verification - Aircraft Emissions
Impact on Air Quality

5. REPORT DATE
Date of Preparations May 1974

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Scott D. Thayer, Douglas J. Pelton,
Glenn H. Stadsklev, and Billy Don Weaver

8. PERFORMING ORGANIZATION REPORT NO.
EF - 262

9. PERFORMING ORGANIZATION NAME AND ADDRESS
GEOMET, Incorporated
50 Monroe Street
Rockville, MD 20850

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-02-0665

12. SPONSORING AGENCY NAME AND ADDRESS
Meteorology Laboratory
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

13. TYPE OF REPORT AND PERIOD COVERED
Final

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT
Under EPA contract, GEOMET has completed a program of air quality measurement, model development and model validation at Washington National Airport.

The measurement program has generated six months of air quality, airport operational, and meteorological data, some of which were used in model development and validation. These data are available on magnetic tape. A new model was developed from the Northern Research and Engineering Corporation (NREC) model. Initially methods for calculating single values of short-term concentrations, for calculating maximum values of short-term concentrations, and for calculating long-term average values of concentrations were changed. The first change involved substituating a single direction only for the superimposed wind direction variability parameter. The next two changes were handled jointly by calculating long-term average concentrations from a sufficiently large sample of single short term values. The NREC model with improvements still consistently underpredicted. Further modifications (improved aircraft classification system, improved aircraft operational modes and pollution emission rates, improved details of airport representation, improved environ area source modeling and emission rates, more representative depiction of line sources, and inclusion of major peripheral highways) were then make. This model with above changes is called the modified (GEOMET) model.

The final result of the validation analysis showed the modified (GEOMET) model consistently predicting near the mean and median values for CO and particulates (from 16% under to 36% overprediction).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Modeling Airport Monitoring Validation Air Quality Data Prediction Measurement Model Development	Meteorological Data Airport Operations Aircraft Emissions One Hour Averages		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 257
	20. SECURITY CLASS *(This page)*	22. PRICE 9.00

EPA Form 2220-1 (9-73)

GEOMET Report Number EF-262

May 1974

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11. a

ABSTRACT

Under EPA contract, GEOMET has completed a program of air quality measurement, model development and model validation at Washington National Airport.

The measurement program has generated six months of records of air quality data, airport operational data, and meteorological data, some of which were used in the model development and validation, and all of which are recorded in edited, processed form on magnetic tape for future use.

The model development work started from a model developed previously by Northern Research and Engineering Corporation (NREC), which had been previously shown by others to generally underpredict concentrations by a factor of about ten. In this project, the first step was to make a number of improvements in implementing the model, without basically changing the model itself. Briefly, these may be summarized as: the use of different methods (from those used by NREC and others): for calculating single values of short-term concentrations; for calculating maximum values of short-term concentrations; and for calculating long-term average values of concentrations. For the first of these three, the change involved the dropping of a superimposed wind direction variability parameter, substituting a single direction only. The next two were handled jointly by calculating long-term average concentrations from a sufficiently large sample of single short term values, rather than the NREC use of the joint frequency distribution of meteorological conditions. This also provides better estimates of maxima than, as NREC does, calculating presumed maxima based on the selection of the meteorological condition judged to cause the highest concentrations. The NREC model with this improved implementation was applied to make estimates of the non-reactive pollutants (carbon monoxide and particulates). This model still consistently underpredicted; however, now the combined estimated station median values were low by factors of three and 1.33, rather than the previously stated factor of ten.

Further more significant modifications were then made to the model, in the form of an improved aircraft classification system, improved aircraft operational modes and pollution emission rates, increased and improved details of airport representation, improved environ area source modeling and emission rates, more representative depiction of line sources, and inclusion of major peripheral highways. This is called the modified (GEOMET) model.

The final result of much validation analysis showed the modified (GEOMET) model as consistently predicting near the mean and median values for CO and particulates (ranging from 16 percent underprediction to 36 percent overprediction); an occasional tendency to overpredict by as much as a factor of two for some of the higher percentile values is explained and can be accounted for in model use. These validation results are without model calibration of any kind.

While there is room for improvement, the model is considered ready for use in airport air pollution analysis. One area of incomplete knowledge, however, lies in the fact that analysis of the concentration contributions from various classes of emission sources has shown airport oriented emissions to be only a very small fraction of the total pollution burden at Washington National Airport. This emphasizes the need for measurement and validation at one or more additional airports, with special attention to those for which the contributions from surrounding highways and environ area sources are comparable to, or less than, those from airport sources.

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ACKNOWLEDGEMENTS

We wish to acknowledge with gratitude the helpful guidance of our first Project Officer, John Zimmerman, and the constructive criticisms of the final report by the second Project Officer, D. Bruce Turner.

SECTION I

SUMMARY

Six months of continuous records of air quality, meteorological and operational data were compiled at Washington National Airport (DCA) under this contract with EPA, and were carefully edited into a comprehensive magnetic tape record. They now represent a significant contribution to the extant body of air pollution and corollary data, and may be further used for development and validation of airport models as they were in this project. The air quality concentration data obtained at eight locations within DCA (see Figure 1) over the six month obervational period (October 1972 - April 1973) are summarized in Table 1.

The model which formed the original base for the work, and which is a joint emissions model and steady-state Gaussian plume dispersion model, had been previously developed under EPA contract by the Northern Research and Engineering Corporation (NREC), as described in NREC Reports 1167-1 and 1167-2. Limited validation informally reported by other investigators showed that basic model as tending to significantly underpredict, generally by a factor of about ten. In this project, the first step was to make a number of improvements in implementing the model, without basically changing the model itself. Briefly, these may be summarized as: the use of different methods (from those used by NREC and others); for calculating single values of short-term concentrations; for calculating maximum values of short-term concentrations; and for calculating long-term average values of concentrations. For the first of these three, the change involved the dropping of a superimposed wind direction variability parameter, substituting a single direction only.

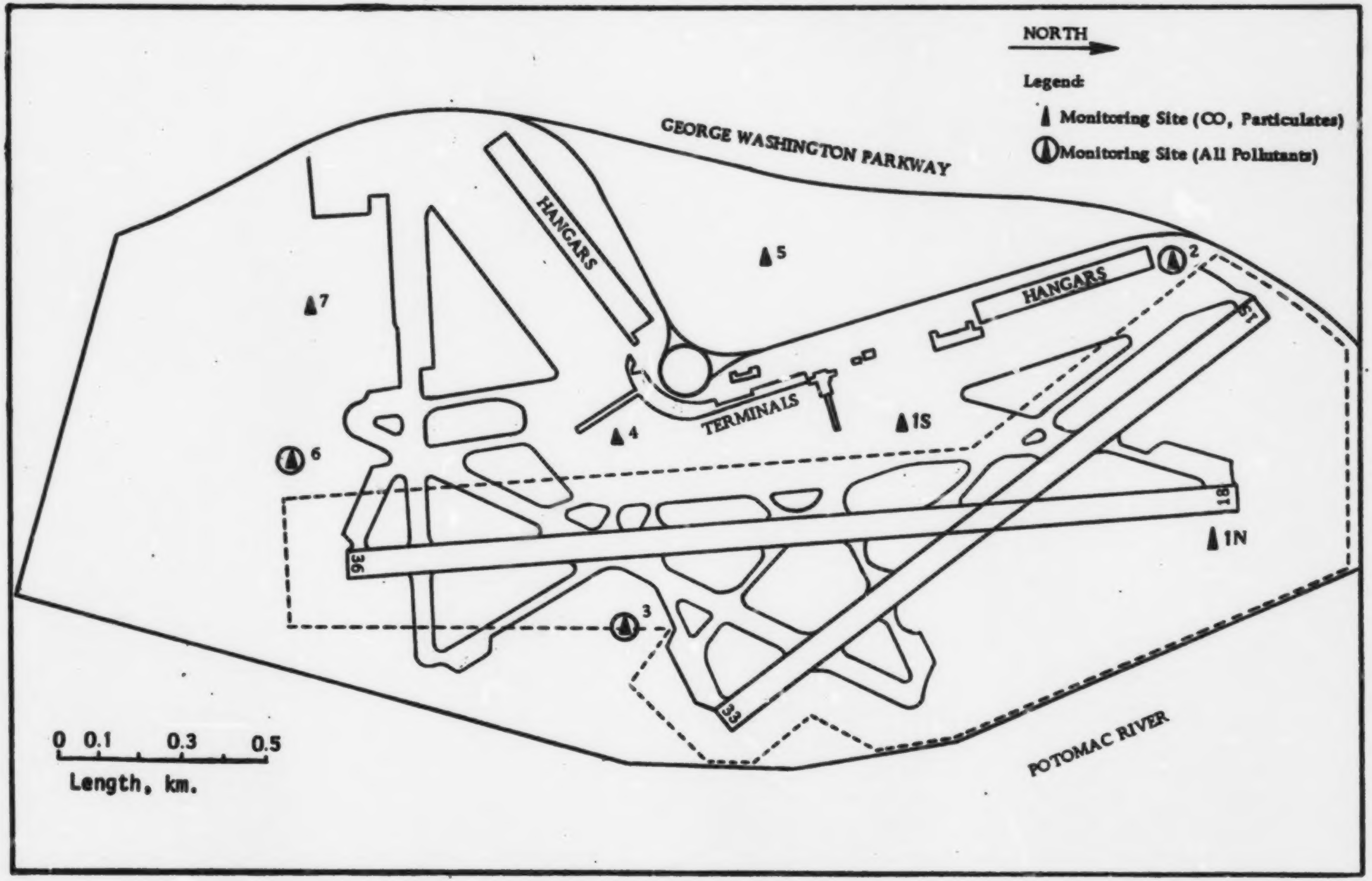
NORTH
Legend:
Monitoring Site (CO, Particulates)
Monitoring Site (All Pollutants)
GEORGE WASHINGTON PARKWAY
HANGARS
HANGARS
TERMINALS
POTOMAC RIVER
1N
1S
2
3
4
5
6
7
15
18
33
36
0 0.1 0.3 0.5
Length, km.

Figure 1. Monitoring Site Locations

Table 1. Summary of Six Months of Air Quality Observations at Washington National Airport

Pollutant	Number of Observations	Median Value	Mean Value	98th Percentile Value	Maximum Value
Carbon Monoxide - 1-hour values, mg/m^3					
Station					
1	1321	1.70	2.48	10.0	19.4
2	1880	1.11	1.52	9.46	16.3
3	2713	1.42	2.10	6.26	10.8
4	3975	3.40	4.43	17.1	60.1
5	4137	2.50	2.99	9.10	19.4
6	1599	1.28	1.52	4.86	9.35
7	4061	2.80	4.97	69.5	88.1
8	1574	1.70	1.84	6.80	11.4
Total Obs.	21,260				
Carbon Monoxide - 8-hour values, mg/m^3					
Station					
1	293	2.14	2.59	9.97	12.0
2	428	1.12	1.52	9.33	9.63
3	619	1.45	2.10	5.74	7.06
4	923	3.84	4.50	12.8	21.6
5	1004	2.66	3.02	7.76	13.6
6	381	1.33	1.53	4.44	7.29
7	920	3.16	5.18	70.0	83.3
8	352	1.64	1.87	6.10	8.10
Total Obs.	4,920				

Table 1. (Continued)

Pollutant	Number of Observations	Median Value	Mean Value	98th Percentile Value	Maximum Value
Non-Methane Hydrocarbons - 1-hour values, μg/m^3					
Station					
2	1922	655	1258	7788	9564
3	2129	166	321	1828	4440
6	1606	1238	1206	2461	4813
Total Obs.	5,657				
Non-Methane Hydrocarbons - 6-9 a.m. values, μg/m^3					
Station					
2	104	465	983	8677	9063
3	73	111	320	2552	2934
6	28	1229	1187	1974	1974
Total Obs.	205				
Nitrogen Dioxide - 1-hour values, μg/m^3					
Station					
2	3489	145	180	488	631
3	3214	104	149	546	639
6	2040	89.6	127	427	623
Total Obs.	8,743				
Particulates - 24-hour values, μg/m^3					
Station					
1	77	62.8	66.4	130	141
2	170	81.9	88.3	180	272
3	149	51.1	54.2	105	144
4	166	93.7	97.9	180	193
5	176	73.6	77.1	149	159
6	150	64.9	68.9	137	267
7	156	128	130	286	436
8	85	63.1	65.6	126	132
Total Obs.	1,129				

The next two were handled jointly by calculating long-term average concentrations from a sufficiently large sample of single short term values, rather than the NREC use of the joint frequency distribution of meteorological conditions. This also provides better estimates of maxima than, as NREC does, calculating presumed maxima based on the selection of the meteorological condition judged to cause the highest concentrations. This procedure also accounts for relationships which may exist between meteorological conditions and emission rates, such as diurnal and/or seasonal variations. The NREC model with this improved implementation was applied to make estimates of the non-reactive pollutants (carbon monoxide and particulates). The predicted medians were 36 percent and 75 percent of the observed medians for the two principal pollutants for validation, CO and particulates, and the predicted means were 52 and 98 percent of the observed values, as shown in validation comparisons with a limited observational data sample selected from early in the six-month sampling period. This method of implementation of the basic model, even without further modification, represents a significant improvement in predictive capability over previous use of the same model, implemented as described in the original NREC study; that performance has been informally reported as underprediction by about a factor of ten by the other investigators who used the model in very limited validation studies.

Principal modifications to the basic NREC model, as implemented in this project, consisted of: a revised aircraft classification system, improved aircraft operational modes and pollution emission rates, increased and improved details of airport representation, improved environ area source modeling and emission rates, more representative depiction of line sources, and inclusion of major peripheral highways. These modifications were made to the model, and some were tested separately for their incremental effect on its predictive capability. The final complete model was tested against the limited dependent data sample referred to above, and also against a much larger independent data sample selected from over the entire sampling period. The results of these and other tests are summarized in the material which follows; these results must be considered in light of the fact that the model is primarily intended to predict for nonreactive pollutants -

thus the verification results for the reactive pollutants (NO_2 and nonmethane hydrocarbons) should be interpreted in that light. In addition, when the large independent sample of CO observations was examined in detail, it became evident that the distribution was notably lacking in the higher values characteristic of the total data sample, even though the model predicted them as before. This development, plus some evidence that the model will overpredict in some special circumstances, required special analysis of these data, including the total data sample. The results given in Table 2 are the distillate of those analyses. These are comparison ratios of predicted to observed values, so that the closer the value is to unity, the better the prediction.

In broad terms, the columns headed GEOMET/Dependent data and GEOMET/Independent data show a quite satisfactory capability for the medians and means for CO and particulates (from 16 percent underprediction to 36 percent overprediction), and is even surprisingly good for non-methane hydrocarbons (nitrogen dioxide is consistently overpredicted, because the pollution assumes that all the NO_x is NO_2). The higher percentile values are somewhat overpredicted, by about a factor of two in some cases, for reasons discussed in the report. Thus the model must be used with judgment when the higher percentiles are of primary concern. However, the overall performance of the model, especially in the context of previous airport modeling, and pollution modeling in general, is remarkably good. None of the validations involved "calibration" of any kind.

Accepting the model validity as indicated, and analyzing within the model the relative contribution of the various classes of emission sources to the pollution concentrations, we see that aircraft and airport emissions represent, for Washington National Airport, only a very small fraction (of the order of a few percent) of the total pollution concentration burden, except on a few occasions. The great majority is contributed by the surrounding major highways and environ area sources. Setting aside the operational significance of this finding as not properly part of this project, it even more strongly indicates the need for verification of the model at one or more additional airports with significantly less nonairport pollution.

Table 2. RATIOS OF STATISTICS OF THE NREC AND GEOMET MODEL PREDICTIONS COMPARED TO THOSE OF THE OBSERVATIONS FOR VARIOUS DATA SAMPLES

	NREC model and dependent sample	GEOMET model and dependent sample	GEOMET model and independent sample
		Carbon Monoxide	
Median (Pred./Obs.)	0.36	1.03	1.02*
Mean (Pred./Obs.)	0.52	1.34	1.36*
98th Percentile (Pred./Obs.)	0.58	2.36	2.22*
		Particulates	
Median (Pred./Obs.)	0.75	0.86	1.09
Mean (Pred./Obs.)	0.62	1.03	1.17
98th Percentile (Pred./Obs.)	0.98	1.90	1.49
		Non-Methane Hydrocarbons	
Median (Pred./Obs.)	0.14	1.33	0.91
Mean (Pred./Obs.)	0.27	2.17	1.04
98th Percentile (Pred./Obs.)	0.35	2.95	1.93
		Nitrogen Dioxide	
Median (Pred./Obs.)	0.42	1.59	2.45
Mean (Pred./Obs.)	0.99	3.63	5.08
98th Percentile (Pred./Obs.)	3.57	18.77	14.62

* This CO case represents a larger sample than the independent one - see text for details and discussion.

SECTION II

RECOMMENDATIONS

1. That, as planned by the sponsor, the data tape be used by the government and other interested agencies for future study of air pollution, and air pollution at airports.
2. That, the GEOMET model being considered ready for use in its present form as a satisfactory tool for the investigation of airport air pollution, it should be used for that purpose.
3. That further investigation be made along the lines suggested in the report to provide a satisfactory means for accounting for the slight tendency of the model to overpredict at higher percentiles under certain conditions.
4. That investigations be conducted at one or more additional airports, involving both air quality monitoring and model validation, to determine the model's performance at airports with considerably less background air pollution than is present at Washington National Airport.
5. That, if further investigations at one or more additional airports are not planned for the near future, the existing developmental computer program be prepared for operational use, a user's manual be prepared (covering a description of the model, a program statement, the conversion of operational data to input data, preparation of input data, use of the model, and example cases), and the model thus be made more generally available to potential users.

SECTION III

INTRODUCTION

Objective of the Project

GEOMET, Incorporated under contract to EPA (Contract Number 68-02-0665) has undertaken the task of modifying and verifying an aircraft emissions/airport air quality model utilizing air quality, meteorological, and emissions data which GEOMET collected in a multi-phased operation. The first airport selected for the data gathering operation was Washington National Airport. Although additional airports may be scheduled for later data gathering the results of the Washington National Airport phase are presented in this report.

The basic model which EPA provided to GEOMET was developed by Northern Research and Engineering Corporation (NREC) under EPA Contract Number 68-02-0085.

The basic objectives of GEOMET on this project are: to review the NREC model (as supplied by EPA); to collect air quality, meteorological, and emissions data over a six-month period; to validate the existing NREC model with a portion of the collected data; to make model modifications and revisions as necessary to allow it to more closely reflect the actual situation; and to validate the modified model using the extensive body of actual collected data.

The output of this project is a validated model, a data tape with the collected data thereon, and a final report summarizing the project.

Scope of Project

The work under this project was conducted according to three major tasks:

- Program planning
- Data acquisition
- Model validation

Task I: Program Planning

One contract requirement was for an early program planning document. The program plan was to describe, in detail, the: air quality sampling equipment and procedures; emissions data acquisition; meteorological data acquisition; acquisition and utilization of relevant data from other studies; edited processed data tape; procedures for model validation; and proposed model modifications.

The program plan was submitted to EPA on October 3, 1972 as GEOMET Report Number E-152. The project then proceeded to follow the program plan.

Task II: Data Acquisition

The six month data acquisition program, centered on Washington National Airport, was concerned with air quality data, emission data (from airport and non-airport sources), meteorological data, and data reduction procedures.

Details of the data acquisition program are provided in Section IV titled Data Acquisition Program .

Task III: Model Validation

One major objective of this project was to modify the NREC model to allow it to more closely predict air quality at airports and to validate this model so that it would have a known statistical reliability in the predictions. This work and the results are provided in Section V titled the NREC Model, The Modified Model, and their Validation.

One major point to note is that it was specified at the outset that a criteria for model success would be its ability to predict air quality levels at the airport so that these can be compared to the National Ambient Air Quality Standards. One further objective would be the ability of the model to identify, quantitatively and in rank order, the various contributors to the air quality levels, such as: aircraft ground operations, ground support vehicles, environ automobile traffic, and others. It was not known at the outset how well each of the contributors could be isolated, for an airport such as DCA is heavily influenced by the environs.

The conclusions and recommendations presented prior to this section and the material presented in subsequent sections represent one year of concerted and concentrated effort by the GEOMET staff in response to EPA's requirements.

SECTION IV

DATA ACQUISITION PROGRAM

OBJECTIVES

The data collection program for this project was designed to meet several requirements which include:

1. Data to be representative of Washington National Airport (DCA)
2. Data would provide air quality observations which could be compared to air quality standards.
3. Data collection would be conducted over a six month period.
4. The data collection system should be automated to the extent possible.

Combining the above requirements has led to the collection of a set of data that removed, as much as possible, the subjectivity and errors that can become a problem with manually interpreted data.

Automated System

The amount of data collected from a program which includes continuous sampling of many parameters over a six month period is large and an automated data collection and handling system is the most reasonable way to process such a volume. Reliable data acquisition systems that provide data records in computer compatible form eliminate many errors and extra effort that would be required if manual methods of data reduction were used instead. Automated data acquisition systems were used to record data from 24 of the 35 air quality and meteorological parameters routinely collected. The hi-vol data could not be recorded by the data acquisition system nor could the carbon monoxide data from four of the stations.

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Data Representative of Washington National Airport

The air quality measurements made for this program were made at seven locations all of which were on the airport property. Some sampling stations were located as close as possible to the aircraft operations while others were located near the edges of the airport. Meteorological data used in this program have been observed at Washington National Airport (DCA) or in some instances data from Dulles International Airport but in those instances the data have been flagged to identify that it is not from DCA. The number of aircraft operations and the type of aircraft involved are taken from records and observations at DCA.

Standard Units

One of the principal objectives of the air quality observations was to insure that the data recorded were in units comparable to the published air quality standards. Consequently, nitrogen dioxide was the only oxide of nitrogen measured. The hydrocarbon analyses include total hydrocarbons and methane in order to provide information necessary to calculate non-methane hydrocarbons concentrations. Ozone was used as a measure of photochemical oxidants since this is the principle of the reference method for measuring photochemical oxidants. Particulate concentrations were measured using the standard high volume samplers (Hi-Vol) for a 24-hour period; and carbon monoxide was monitored continuously to enable determination of the required one-hour and eight-hour values.

The data collected during the six month period are comparable to short term air quality standards and provide a good approximation of long term (annual average) standards.

COLLECTED DATA

Air Quality Data

Air Quality Observations - Continuous - Air quality data collection was scheduled for a six month period beginning the first of October through April 1973. The actual duration of sampling varied among stations according to the delivery dates of the various air quality monitors. Gaseous pollutants monitors were designed for continuous operation, but continuous particulate data were provided by locating two Hi-Vol samplers at each station and programmed to run on alternate days.

Site locations - An array of seven monitoring sites was located at National Airport. The sites were chosen to ensure that pollutants which originate from sources outside the bounds of the airport would be measured as they move across the airport as well as those emissions which are the result of activities at the airport, and that the population exposure to maximum concentrations would be adequately assessed. Figure 1 shows the sampling site configuration. Approval of each site was dependent on several considerations. Important among these considerations was the availability and accessibility of electrical power, approval from Airways Facilities Sector to ensure that navigational aids would not be interfered with, and approval from the Airport Operations Office to ensure that airport safety regulations would not be violated. The monitor site configuration shown in Figure 1 had taken these points into consideration and the locations indicated represent our judgement of the best combination that could be used.

Figure 1 (p.2) shows the approximate boundaries (dashed line) of the restricted areas of the airfield in which sampling shelters may not be installed. An exception to the restricted area was made for site 1N due to the fact we were able to locate the station at a point low enough that it would not interfere with the navigational aids located nearby.

To summarize, criteria for the site selection of monitoring equipment included the following:

- Location in "unrestricted" areas. Unrestricted is used here in the sense that the site had been approved by the Chief of Operations at DCA and by the Chief of Airways Facilities Sector at DCA.
- A reasonably close access to electrical power source.
- An overall design amenable to adequate coverage of the pollutant dispersion.
- Site selection which would enable differentiating between pollutants generated on the airport and non-airport emissions.
- Adequate coverage of publicly accessible areas.

Site descriptions - Station 1 was located at the position marked 1S on Figure 1 for the first three months of the sampling then moved to location 1N for the final three months. The ground surface at 1S was grassy over most of the area but concrete on the west end of the shelter where the Hi-Vols were located. The area at DCA is designated Fuel Pad No. 2. This area is about 400 feet south of an area where most private aircraft taxi to and from in order to park. During times when landing and takeoff operations are to the south most of the scheduled airline traffic taxi within 200 feet of location 1S. At location 1N the ground surface was asphalt paved. The Potomac River was directly east and the end of runway 18 was about 200 feet to the west.

Station 2 was on the northwest side of the airport about 350 feet north of the north hangars, approximately 200 feet east of the George Washington Parkway, and 300 feet from the end of runway 15. Features of this location permitted sampling of pollutants generated on the highway during westerly winds and airport generated pollutants during southerly and easterly winds. The ground surface at station 2 was hard packed dirt.

Station 3 was located about 1800 feet east of the main terminal building and 700 feet east of the main runway (runway 18-36), and is thus situated where most of the aircraft emissions would be sampled during westerly winds. During easterly wind flow, it will monitor pollutants from the D.C. metropolitan area. The ground surface at Station 3 was grassy.

Site 4 was a location which provided data for pollutant levels close in to a major passenger loading and discharge area. The auxiliary power unit and service vehicle emissions, plus the aircraft engine emissions during start-up and taxiing, were indicated at this location of high personnel access, as well as the general outdoor-terminal-area pollutant levels. Station 4 was located close in to the main terminal building where the ground surface was asphalt pavement.

Station 5 was about 2000 feet west of the main runway and 700 feet east of the George Washington Parkway. There were parking lots close to this station on 3 sides and a one story building on the east. The ground surface at the station was packed dirt.

Station 6 was very close to the south end of the main jet runway and monitored emissions from aircraft as they begin to run up the engines for takeoff into northerly winds and monitored emissions from idling aircraft queued for takeoff. During southerly winds, it provided measures of non-airport environ pollutant levels. Station 6 was about 400 feet from the south end of runway 36 and from the taxiway used most frequently for take off during northerly winds. The ground surface was dirt.

Station 7 was located at the edge of a 1000 car parking lot on the southwest side of the airfield about 2,050 feet west of the main runway. It can provide a measure of dilution of pollutants between Site 6 and 7 during easterly winds. It is in an area where a good deal of airport/non-airport emissions can be measured. During southerly wind flow, Sites 6 and 7 will measure non-airport environ pollutant levels. Site 7 was also at a shelter where aircraft crews frequently wait for a bus to transport them from the adjacent employees parking lot to the main terminal, and thus provides another location for measuring pollutants where personnel exposure is likely to be high. The ground surface at Station 7 was asphalt pavement.

There were two combinations of pollutants measured. At four of the stations (type 1 stations) particulates and carbon monoxide were sampled while at the other three (type two) stations, particulates, carbon monoxide, hydrocarbons, ozone and nitrogen dioxide were measured. At those three stations paper tape samplers were installed so the coefficient of haze could be calculated. The combinations of station and pollutants sampled are shown in Table 3.

Table 3. AIR QUALITY SAMPLING NETWORK

Pollutant	Detection Principle	Sampling Frequency	Monitor Site Number						
			1	2	3	4	5	6	7
CO*	NDIR	Continuous	X			X	X		X
CO**	Flame Ionization	"		X	X			X	
NO_2	Colorimetric	"		X	X			X	
O_3	Chemiluminescence	"		X	X			X	
HC	Flame Ionization	"		X	X			X	
Particulates	Gravimetric (Hi-Vol)	24-hour	X	X	X	X	X	X	X
Particulates	Spot Tape	1-hour		X	X			X	

* EPA-furnished equipment. (MSA instruments used for various programs by EPA and its contractors).

** GEOMET-furnished equipment. (Byron gas chromatographs).

Station description - Each station consisted of an 8 x 16 foot office-type trailer, which provided housing for the instrument and work space for servicing the equipment. Each station had electric heat and air conditioning for temperature control. The roof of the station was ten feet above ground level. The sample air intake extended four feet above the roof. At the type 1 stations the sample air was moved from the outside through the analyzer by the pump on the analyzer. On the type 2 stations sample air was continually moving through a glass-teflon intake system, by using a pump on the exhaust end of the system. Sample air to each analyzer was pumped out of a manifold in the station by the pumps installed in each of the analyzers.

Data recording - The measured pollutant levels were recorded either on strip charts or by an automatic data acquisition system (DAS) depending upon monitor type. The CO concentrations measured with the EPA-furnished MSA analyzers were recorded on the strip chart recorders supplied with the analyzer. The Hi-Vol particulate filter analyses were conducted by a local laboratory and the resulting data entered into the system via punched cards. The HC, CO, O_3, NO_2 and spot tape sampler data at the type 2 stations were recorded in real time on punched paper tape and hard copy, using an automatic DAS built by Monitor Labs. The automated system is the Model 7200 Automatic Data Logger. The meteorological data were fed into the DAS at Station 3.

Each analyser or meteorological sensor was assigned one channel on the DAS. The DAS was programmed to scan each channel once every five minutes, thereby providing twelve values for each parameter every hour. Thus, the hourly average of each parameter is the average of the values from each five minute scan. The DAS was programmed to insert date-time headings at the beginning of each scan. Channel identification was recorded also.

Carbon monoxide data at the four type one stations were recorded on strip charts using the Leeds and Northrup Speedomax W recorder with a chart speed of one inch per hour.

Instrumentation used for air quality analysis of particulates - High Volume air samplers (Hi-Vols) were used to collect suspended particulates on 8x10 inch filters. Seven of the Hi-Vol's had pressure transducers with recorders attached to provide a record of air flow through the Hi-Vol. Flow rates for the seven remaining Hi-Vols were determined by averaging the flow rate observed on a visifloat at the beginning and end of each sample.

The Hi-Vols were calibrated whenever the motor brushes were changed or the motor repaired. Calibration was done using the procedure described in the Federal Register, Volume 36, Number 84, Part II, Appendix B.

Carbon monoxide concentrations were measured at the type 1 stations using the Mine Safety Appliances (MSA) Model 200 LIRA. The MSA units use the infrared absorption principle to measure CO concentrations. Calibration of the MSA units was done using "zero air" and a span gas of 83 ppm of CO in "zero air". The MSA units normally operated in the low range (0-100ppm) but are equipped to automatically switch to a higher range (0-300ppm) if the concentrations of CO reach the upper end of the low range. Zero and span checks were made at least three times per week and sometimes more frequently.

Carbon monoxide was measured at the type 2 stations using a gas chromatograph which also measured methane and total hydrocarbons. The chromatograph used was the model 233A produced by Byron Instruments. Model 233A provided an information storage option which stored the peak value of CO, CH_4 and THC during each five minute sample cycle. Pollutant concentration in the chromatograph were measured with a flame ionization detector.

Calibration of the gas chromatograph was done using a span gas with 30 ppm of carbon monoxide and 30 ppm of methane. Calibration on the gas chromatographs was done every 7 to 10 days of operation.

Nitrogen dioxide was measured using Monitor Labs Model 8102A Analyzer. The Modified Saltzman reagent was used in the Monitor Labs analyser and a true ratio photometer which determines NO_2 concentrations colorimetrically by comparing the ratio of sample output to a reference output. The reagent for each monitor was prepared in five gallon lots which provided enough reagent for ten days of continuous operation. The NO_2 monitors were calibrated each time a change of reagent was made.

Calibration was done using the Monitor Labs series 8500 Permacal calibration unit. The NO_2 calibration unit has a permeation tube and provides a dynamic calibration system. Ambient air drawn through an activated charcoal filter was used for clean air while zeroing the analyzer.

Ozone was measured with the TriTech Model 4820A ozone monitor which uses chemiluminescence detected with a photo multiplier tube. The ozone monitor was calibrated using a TriTech Generator-Calibrator Model 4801 to provide a constant known concentration of ozone to the analyser. The generator-calibrator was calibrated using the KI reference method at the onset of the project and again near the middle of the project.

Suspended particulates were also measured using paper tape samplers. The tape sampler used was the Research Appliance Company (RAC), Model G2. This model measures percent of light transmission continuously. The soiling index data were not a required part of this project but the data have been recorded. The tape samplers were initially located in each of the type 2 stations, and all were operating on a one hour cycle. On February 16 the tape sampler from Station 6 was moved to Station 2 and programmed to cycle to a new spot every two hours while the other tape sampler was programmed to cycle every hour. On March 3 the intake for the sampler programmed for two hour samples was moved from the manifold to a position which would allow sample air to move in a straight line from outside to sampler. Finally, on March 16 the sampler that had been on a two-hour cycle was changed back to a one-hour cycle. The difference between the two tape samplers at that station then being one sampler intake coming off the manifold and the other coming straight in to the sampler from an intake height of four feet above the ground surface.

Intermittent - Air Quality Observations

Grab sampling - Grab sampling experiments were originally included in the program plan to provide guidance in site selection for the continuous monitoring stations. The grab sampling for that intent could not be conducted prior to location selection because the analyzers were not available until after the station locations had to be selected. Grab sampling was done later in the program and the sample air analyzed for carbon monoxide concentrations to determine if there were any areas on the airport with particularly high concentrations of CO.

In the grab sample experiments ambient air was pumped into an aluminized polyester bag which was then brought to a MSA unit for CO analyses.

The sample period was to be one hour but the actual sampling period ranged from 45 minutes to 75 minutes. Sample intake level was four feet above the ground level. Some of the grab sampling was done in the vicinity of the monitoring sites to determine if there was a gradient of carbon monoxide concentrations from nearby sources.

On January 17, grab samples were collected in the vicinity of Station 2 which is at the north end of the airfield, near the confluence of the George Washington Parkway and Smith Boulevard.

On January 26, grab samplers were set up at Station 3 in the afternoon.

Station 3 is located on the east side of the airfield approximately 700 feet east of the main runway. Sample 3-4 was closest to the main runway (approximately 320 feet east of runway). Grab sampling has not demonstrated any strong gradients of CO, but the number of samples is small and may not represent the usual distribution of carbon monoxide.

Table 4 lists the locations of the samplers and the concentrations of CO analyzed for each of the samples.

Table 4. GRAB SAMPLER LOCATIONS JANUARY 17 & 26

Date	Sampler Number	Location	CO Concentration (ppm)	Winds
Jan 17	2-1	100 ft. S. of highway	--	
Jan 17	2-2	270 ft. S. of highway	3.0	3-4 mph from 160 to 180 degrees
Jan 17	2-3	500 ft. S. of highway	3.5	
Jan 26	2-4	10 ft. S. of highway	6	0.8 to 3.0 mph primarily from 030 to 080 degrees
	2-5	50 ft. S. of highway	6	
	2-6	150 ft. S. of highway	8-10	
	2-7	370 ft. S. of highway	6	
	3-1	100 ft. W. of station 3	2.0	2.8-4.0 mph from 160 to 200 degrees
	3-2	200 ft. W. of station 3	2.2	
	3-3	300 ft. W. of station 3	2.0	
	3-4	380 ft. W. of station 3	3.5	

Another series of grab sampling was done during April as part of an intensive study period. Those data are discussed in detail in Appendix C.

Trace element sampling Trace element concentrations in the ambient air were measured at National Airport during the last eight days of February 1973. The sampling and analysis were provided through an agreement with members of the Chemistry Department at the University of Maryland who were working under Grant No. GI36338X, from the National Science Foundation in the Research Applied to National Needs (RANN) program. Samples were collected at five of the stations by drawing air through 47mm Neucleopore membrane filters for 24 hours. Once the membrane filters start to clog they will collect particles down to 0.2 micron. To avoid metal contamination, sample holders made of teflon-nylon or polycarbonate-silicon combinations were used.

After collection, the filters were folded into eights, sealed in acid-washed polyethylene bags and irradiated at the National Bureau of Standards reactor in Gaithersburg, Maryland and subsequently analyzed for trace metals according to accepted Neutron Activation Analysis techniques (Gordon and Zoller, Anal. Chem. February 1970). A few of the samples were collected using a six stage Science Advances CI-6 cascade impactor. Particles were collected on a 1 mil, 1 square inch polyethylene disc. Subsequent processing was similar to the procedures just described.

Table 5 presents some results of the analysis of the samples collected. The results given in Table 5 are averages of all samples taken at Washington National Airport and a comparable body of data from Friendship Airport near Baltimore, Maryland. The 20 samples at DCA were taken over an 8 day period. Data from Friendship Airport were collected at several sampling sites over a 3 day period. Data from Friendship Airport were provided by the University of Maryland as additional data because they had conducted a similar sampling program there. More detailed data regarding trace metals analysis will be provided in a future report (Conry, 1974) of research conducted under the previously cited NSF grant which is directed by G. E. Gordon, Department of Chemistry, University of Maryland.

The sample concentrations have been normalized with respect to the abundance of those elements in the earth's crystal rock by dividing the sample concentration of each element by the sample concentration of aluminum then dividing that ratio by the ratio of the element to aluminum in the earth's crust.

Meteorological Data

Meteorological data used for model validation were collected at National Airport either directly by sensing equipment installed by GEOMET or from the National Weather Service records.

Table 5. Average Absolute and Normalized Elemental Concentrations of Elements Present on Particulate Matter Collected at Friendship and National Airports

Element	Average Concentration (ng/m^3)		Normalized Concentrations	
	National (20 spls.)	Friendship (13 spls.)	National	Friendship
Na	430	160	0.96	0.79
Ca	740	580	1.4	2.2
Ba	35	11	3.3	2.4
Cl	520	760	76	25
Br	360	350	7,400	13,000
Al	1,400	720	≡1.00	≡1.00
Sc	0.66	0.15	2.1	1.2
V	90	30	61	35
Cr	39	5.4	26	8.3
Mn	37	20	3.2	3.1
Fe	1,100	660	1.8	2.0
Co	1.4	0.5	6.6	4.6
Cu	48	26	89	100
Zn	190	44	170	86
As	28	2.1	700	140
Se	4	1.2	2,500	1,500
Sb	20	1.5	4,400	800
La	2.0	0.95	2.3	2.3
Sm	0.23	0.10	1.8	1.7
Eu	0.08	0.014	2.9	1.1

Observed Data - Meteorological data from installed sensors were recorded on paper tape and hard copy via the data acquisition system at five minute intervals in the same manner as air quality data. The parameters thus recorded were temperature, wind speed, wind direction, standard deviation of the wind direction and precipitation. A photometer to measure solar radiation was installed and those measurements recorded also. The meteorological sensors were installed at Station 3 which was approximately 450 feet away from the National Weather Service sensors. This location afforded the best exposure for the sensors of the available locations. A tower near Station 3 did cause some interference to the wind sensors when the wind was blowing from the sector between 45-90 degrees.

Interference in this case means somewhat reduced wind speeds and a larger variation in wind direction. Winds from that sector are not particularly common as can be seen from the wind roses shown in Appendix A.

The wind speed and direction measurements were integrated to produce a 5-minute average. Instantaneous values of the solar radiation and temperature sensors were recorded. The rain gage, wind and temperature sensors were standard equipment ordered from Meteorology-Research Incorporated.

The heated raingage, Model 302, signalled an event at each tip of the bucket which indicated 0.01 inch of precipitation.

The wind sensor was Model 1074 which has a starting threshold of 0.75mph, accuracy of ±0.4mph or 1% (whichever is greater) and a range from 0 to 100 mph.

The temperature sensor, Model 802, had a range of -30°C to +50°C and accuracy of ±0.5°C.

Solar radiation was measured with a system from International Light Inc., using a PT100-CM108 photo dectector and IL200-CM122 photometer. Filters were installed on the radiation detector so it was responsive in the 300-400 nanometer range with a peak response at 360 nanometers.

Derived Data - Meteorological Data which were routinely observed or produced by the National Weather Service at National Airport were gathered and coded for use in this program. Data gathered from the Weather Service include radiosonde soundings and the hourly surface observations recorded on WBAN-10A. Pasquill stability categories A-F were determined from the WBAN-10 observations using a system suggested by Turner (1964).* Tables 6 and 7 indicate the system used to determine the stability category. A computer program was written to determine stability category for each hour using data that were keypunched from the hourly surface observations. That program was used for stability categories during January through April. For the months of November and December, the hourly stability category data were read from a magnetic tape purchased from the National Climatic Center at Asheville, North Carolina.

Hourly values of the mixing depth were interpolated from morning low value to the afternoon value provided by the Environmental Meteorological Support Unit (EMSU) which made radiosonde soundings at National Airport. The method of interpolating between the minimum and maximum mixing ceilings is to:

1. Use the morning minimum from midnight to 6a.m.
2. Linearly interpolate between the minimum and the maximum between 6a.m. and 2p.m.
3. Use the afternoon maximum between 2p.m. and midnight.

This pattern of diurnal variations is illustrated in Figure 2.

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*Turner, D. Bruce, 1964. "A Diffusion Model for an Urban Area". Journal of Applied Meteorology 3(1),83.

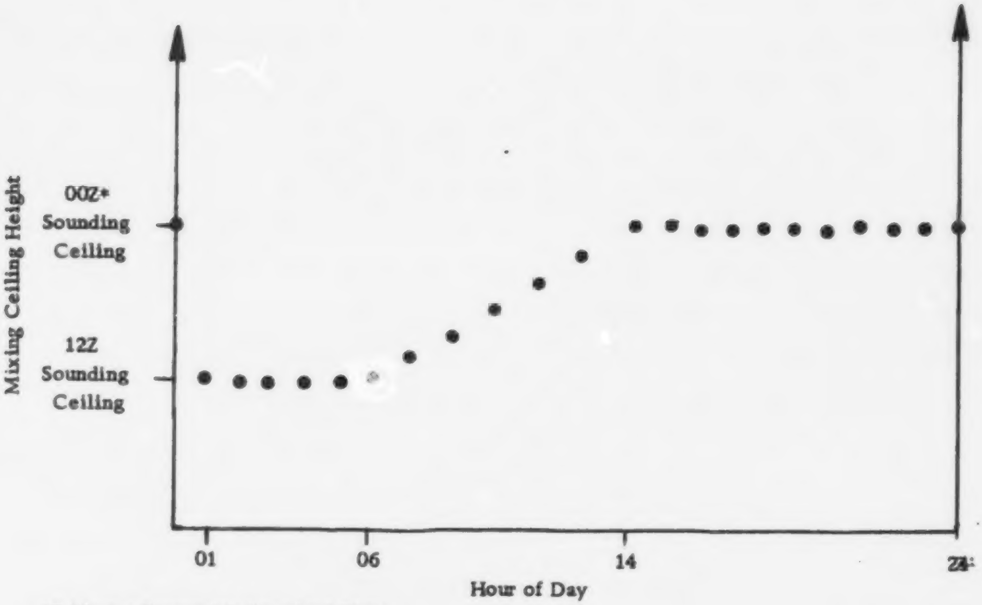
Table 6. Meteorological Stability Classifications for Characterizing the Diffusion Parameters (σ_y and σ_z)

Wind Speed (Knots)	Stability Class for Indicated Net Radiation Index *						
	4	3	2	1	0	-1	-2
0, 1	A	A	B	C	D	E	E
2, 3	A	B	B	C	D	E	E
4, 5	A	B	C	D	D	E	E
6	B	B	C	D	D	E	E
7	B	B	C	D	D	D	E
8, 9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
≥ 12	C	D	D	D	D	D	D

*Net Radiation Index Values are Given in Table 3.

Table 7. Net Radiation Index Values

Time of Day	Total Cloud Amount (t)	Ceiling (c), (ft)	Net Radiation Index for Indicated Solar Altitude (a)			
			$a \leq 15^\circ$	$15^\circ \leq a \leq 35^\circ$	$35^\circ \leq a \leq 60^\circ$	$a > 60^\circ$
Night	$t \leq 0.4$	--	-2	--	--	--
Night	$0.4 < t < 1.0$	--	-1	--	--	--
Night	$t = 1.0$	$c < 7{,}000$	0	--	--	--
Night	$t = 1.0$	$c \geq 7{,}000$	-1	--	--	--
Day	$t < 1.0$	$c \geq 16{,}000$	1	2	3	4
Day	$0.5 < t < 1.0$	$c < 7{,}000$	1	1	1	2
Day	$0.5 < t < 1.0$	$16{,}000 > c \leq 7{,}000$	1	1	2	3
Day	$t = 1.0$	$c \leq 7{,}000$	0	0	0	0
Day	$t = 1.0$	$16{,}000 > c \geq 7{,}000$	1	1	1	2
Day	$t = 1.0$	$c \geq 16{,}000$	1	1	2	3



*Z Means Greenwich Standard Time

Figure 2. Graphical Model of Procedure Used to Interpolate in Time Between Mixing Ceiling Estimates Obtained for Radiosonde Observing Times.

The EMSU has provided an air stagnation potential sheet for all the normal work days which were included in the six month sampling program. Along with other information on that sheet, five mixing depths are included which are; a) maximum yesterday, b) minimum this morning, c) maximum this afternoon, d) minimum tomorrow morning, and e) maximum tomorrow afternoon. Whenever available, parts a) and b) were used in the interpolation scheme. Parts c), d) or e) were used if the corresponding part a) or b) were missing.

During February the Sperry-Rand Mark II Thermasonde was made available by EPA to be installed at the airport for collection of comparative data to be subsequently analyzed by EPA.

The Thermasonde is a device used to determine the vertical temperature profile of the atmosphere up to about 1800 meters. It is a remote sensing device which was programmed to make a scan once each hour. Using the trace which was recorded on a strip chart, a vertical temperature profile can be reconstructed. A more detailed explanation of the precedure for analyzing the Thermasonde traces can be found in Appendix B.

An estimate of the mixing depth for that hour was made using the temperature profile. Mixing depths derived from the interpolation method and from the Thermasonde trace are both recorded on the processed data tape, with identification as to which method is represented.

Additional and Supplemental Information

Aircraft Activity - A log of aircraft activity was available from the Federal Aviation Administration which provides the number of take-offs and landings during each hour. The information was available for the following categories:

Air Carrier Scheduled Operations
Air Taxi Operations
General Aviation Operations
Military Operations
Hourly Total

These data were coded and keypunched (except military) and read on to the processed data tape. Air carrier operations include the major portion of aircraft activity; about 70-75 percent of the operations at National Airport are in this category. Most all of the large multiengine jets are counted in the air carrier category, air taxi operations account for about 10 percent of the aircraft activity. Some of the smaller jets and multiengine propeller planes are in the air taxi category. The general aviation category accounts for 20-25 percent of the traffic and includes a wide variety of aircraft types from very small single engine propeller aircraft to multiengine jets. The distribution of aircraft types within each of those categories was studied during the intensive study period which will be discussed in the next section.

Intensive Study Period - During April and the first part of May a detailed study of aircraft activities at Washington National Airport was conducted; the activities conducted during this period are referred to as the intensive study.

The original objective of the intensive study was to develop an emissions assessment plan to accurately define the sources of concern with respect to the air quality in airport environs on a time and area dependent basis by collecting data regarding:

- Usage patterns and activity of the aircraft utilizing the airport
- An assessment of the strengths and locations of non-aircraft airport emissions
- An assessment of stationary and mobile emission in the area surrounding the airport which influence the air quality of the airport environs.

The emphasis during the intensive study period was on the first two points mentioned. Two of the major air carriers were observed - with regard to ground operations.

Eastern Airlines and United Airlines combined account for about 45 percent of the scheduled arrivals and departures and fortunately use gates which are near to the center of all gates which simplified the task of observing both airlines.

Personnel from Eastern Airlines and United Airlines were interviewed in order to determine what activities to expect around each aircraft. That information was very useful to the observer when he had several aircraft to watch which arrived within a short period of time.

Observations were made between 7a.m. and 7p.m. mostly in the month of April. The exact hours during which observations were made are discussed in Appendix A along with a summary of the data obtained.

Due to restrictions imposed by noise problems scheduled jet operations do not begin until 7a.m., consequently our observations did not start before 7a.m. After 7p.m. in the evening, darkness prevented an observer from keeping track of an aircraft after it departed from the terminal area especially if there was a queue on the taxi way awaiting clearance for take off.

At least three people were required to record the aircraft activities. A natural breakdown of events for each observer was as follows:
Arrival Observations include:

- Runway used
- Point of touchdown
- Time of touchdown
- Time aircraft turns off runway (start of taxi mode)
- Time aircraft arrives at gate (special note of stops or delays while taxiing)
- Aircraft type.

Departure Observations included:

- Type aircraft
- Time taxiing starts
- Taxiways used
- Delays while taxiing
- Time of arrival at runway
- Time of start rolling for take off
- Time of lift-off
- Point of lift-off

The ramp observer(s) recorded the time, type and number of service vehicles which serviced each aircraft:

- The time the aircraft arrives or departs from a gate
- Time of engine start up or shut down
- If an Auxiliary Power Unit is running etc.

Figures 3 through 15 show the aircraft activity data collected. The data thus collected have been used to judge the appropriateness of the existing input data for model validation. The following categories of aircraft operational modes are input parameters to the prediction model:

1. Approach
2. Landing, touchdown, coast (idle), thrust reversal (climb power)
3. Taxi to terminal
4. Maneuvering into gate and engine shutdown
5. Auxiliary power and support vehicle operation
6. Engine start-up and maneuvering from gate
7. Taxi to runway
8. Delay at runway
9. Takeoff
10. Climb-out

The values for some of these modes must be calculated by the model and could not be accurately observed. A more detailed discussion of the values used in the model to describe these operational modes will be presented later in this report.

During the observations of aircraft landing an observer could not accurately time intervals the aircraft touched down and coast until engine reversal and coast at idle power. Observations made of the total time from touch down to turning off the runway mostly depended on which taxiway the aircraft used. Selection of taxiway used was dependent on the terminal gate assigned to the aircraft.

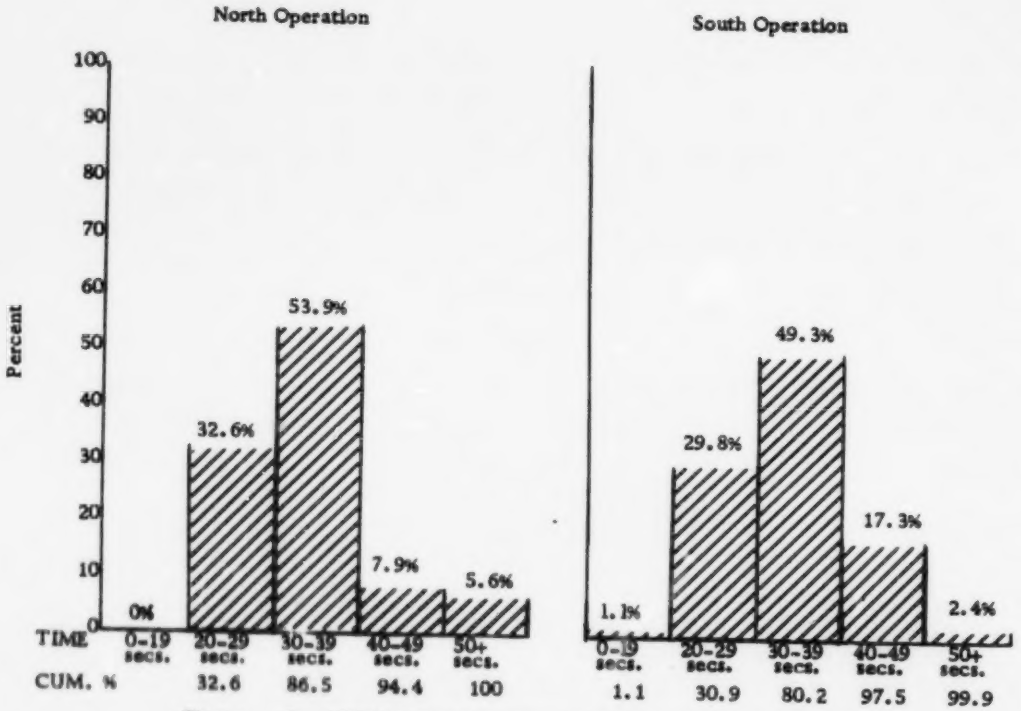
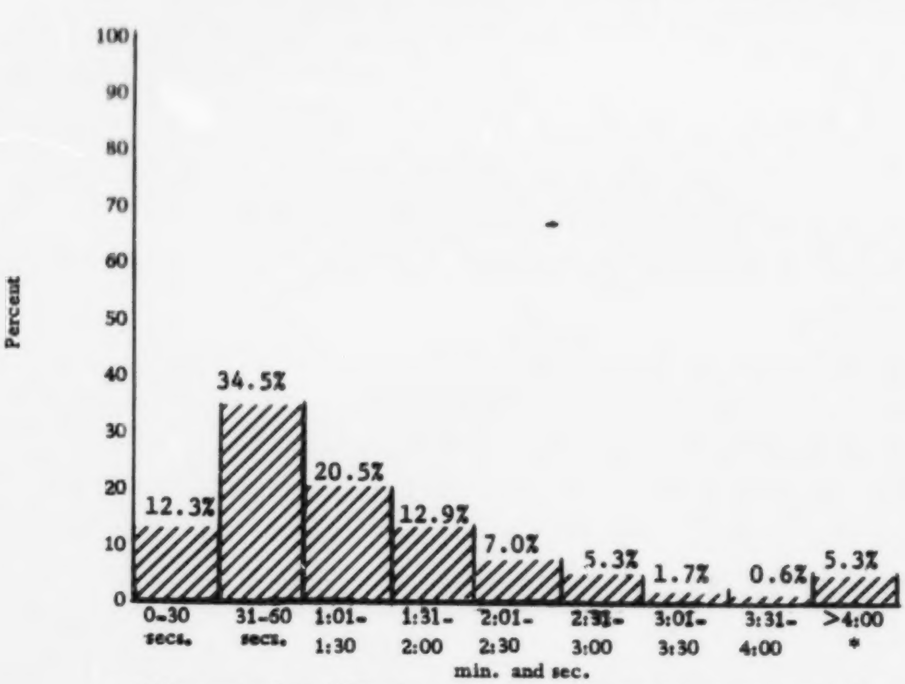


Figure 3. ARRIVALS: Time from Touchdown to Runway Turnoff



*Times range from 4.05 min. to 14.3 min. Elongated times are a result of short stops enroute to terminal.

Figure 4. Taxi Time - Runway to Gate Commercial Aircraft

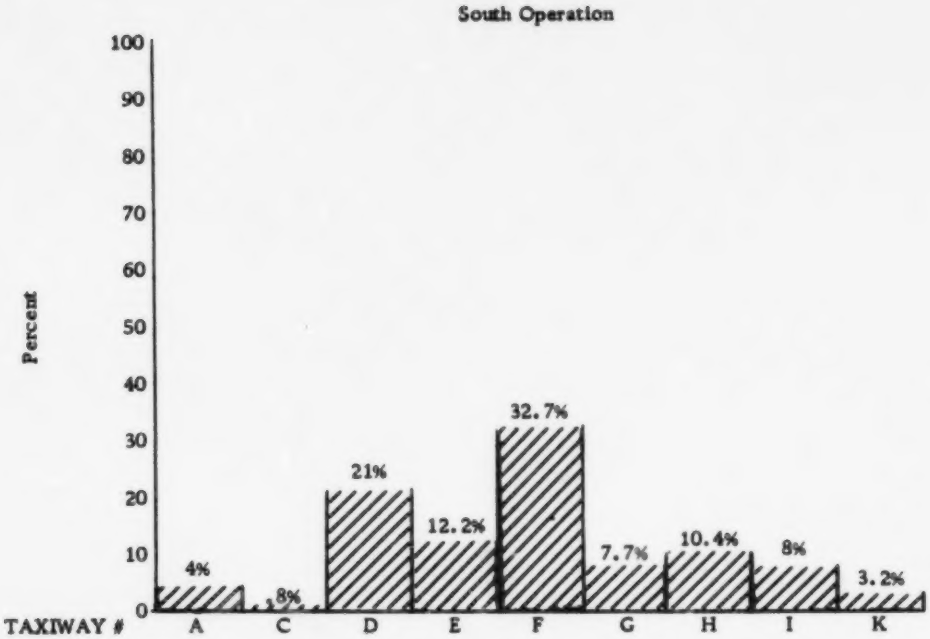

South Operation

Figure 5. ARRIVALS: Percentage Use of Taxiways

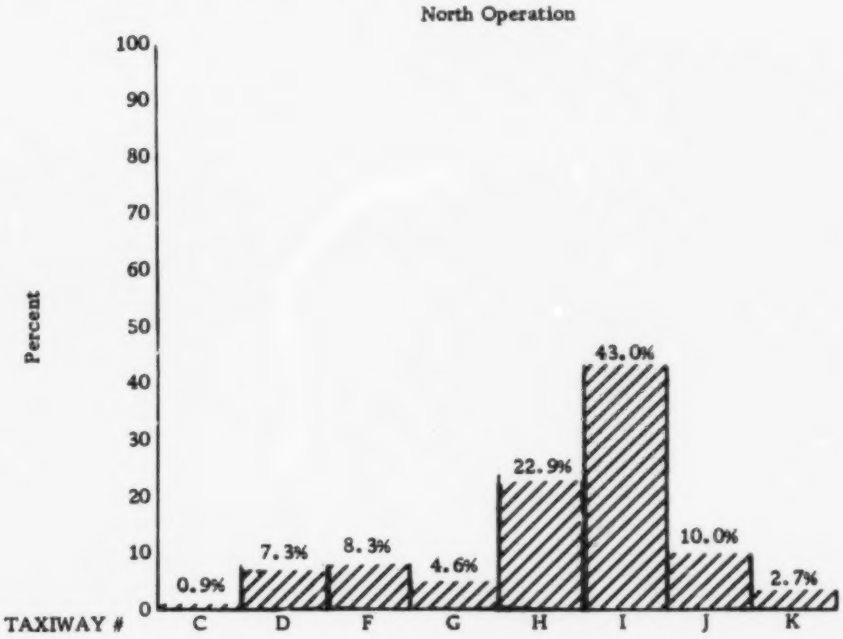

North Operation

Figure 6. ARRIVALS: Percentage Use of Taxiways

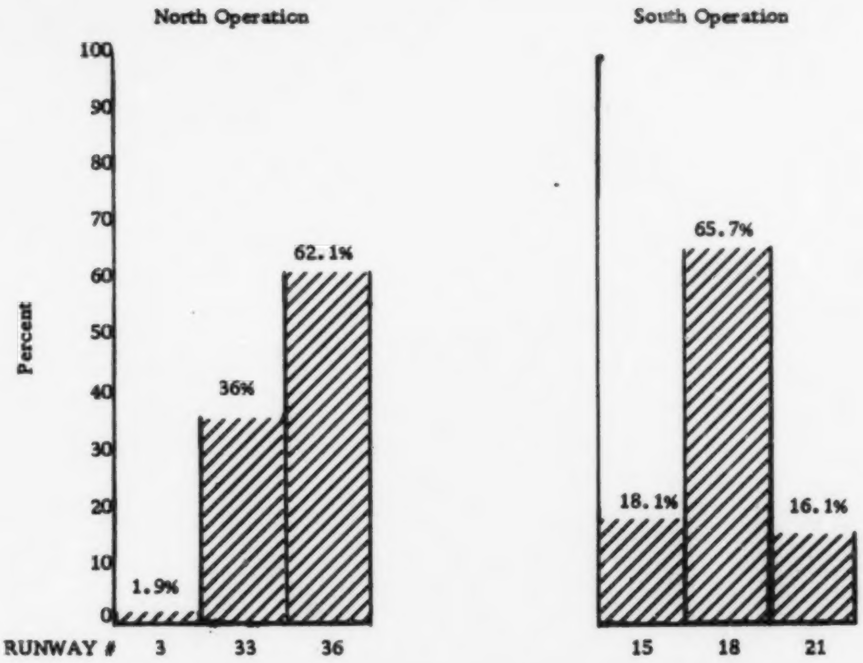


Figure 7. ARRIVALS: Percentage Use of Runways

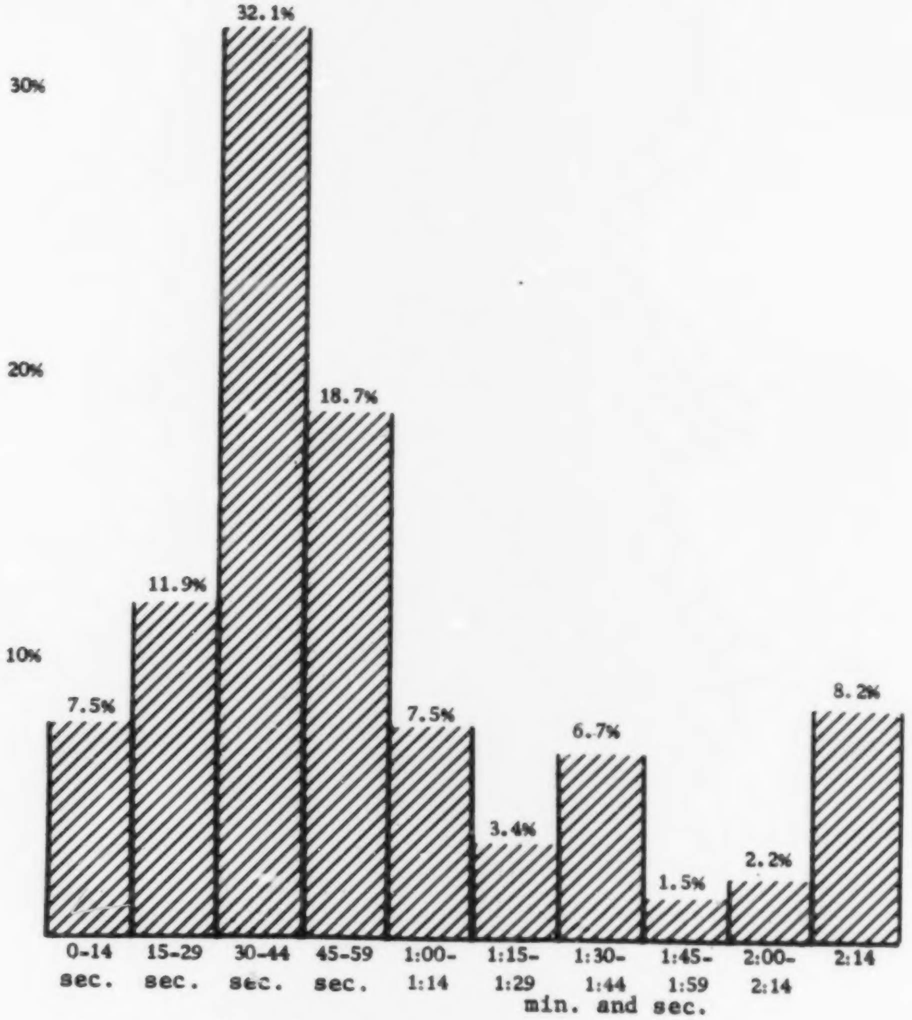


Figure 8. Time from Arrival at Gate to Engine Shutdown

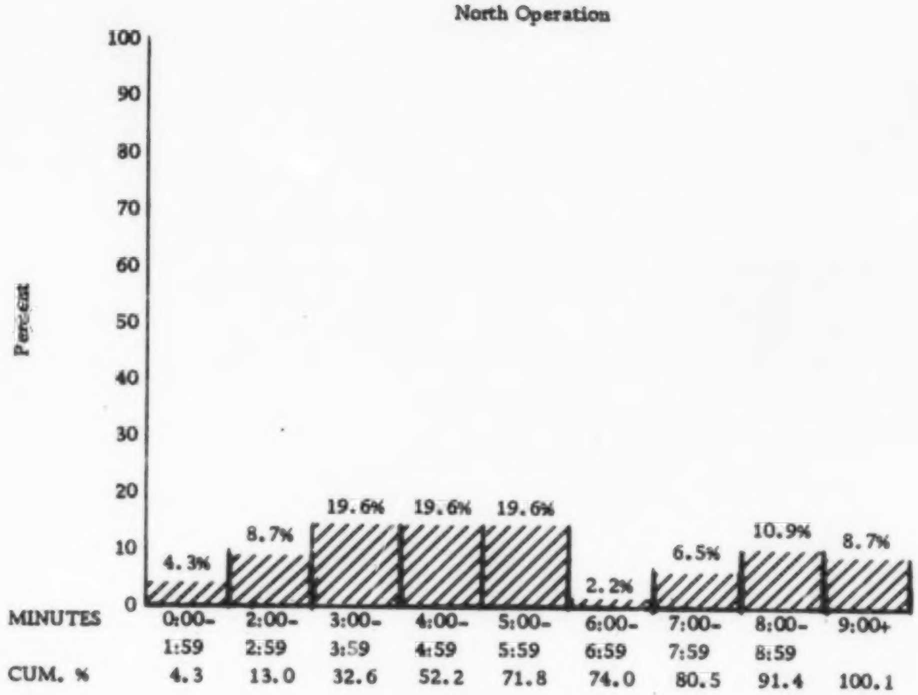


Figure 9. Taxiing Time - Departures

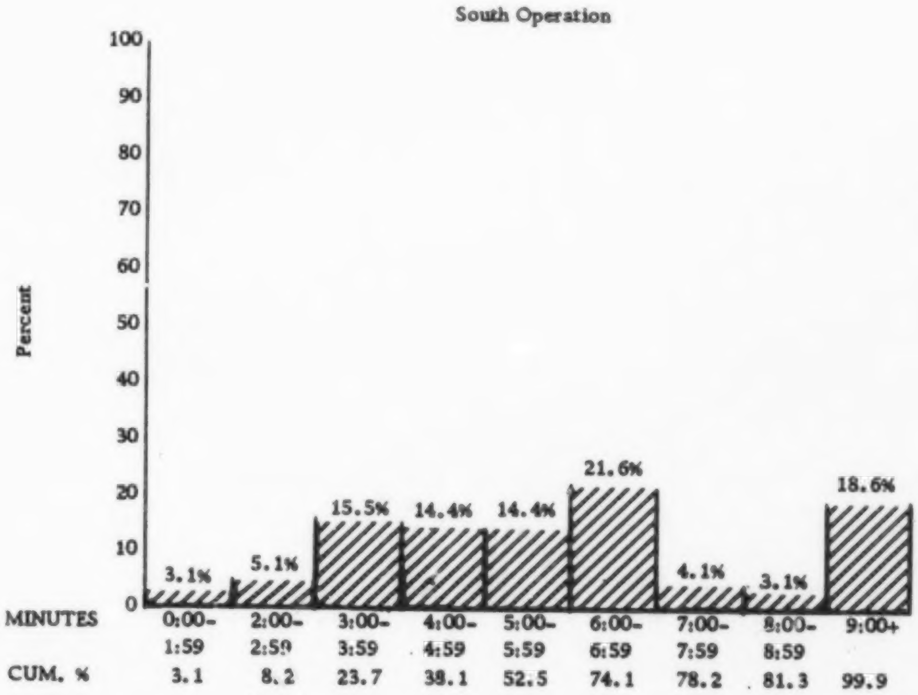


Figure 10. Taxiing Time - Departures

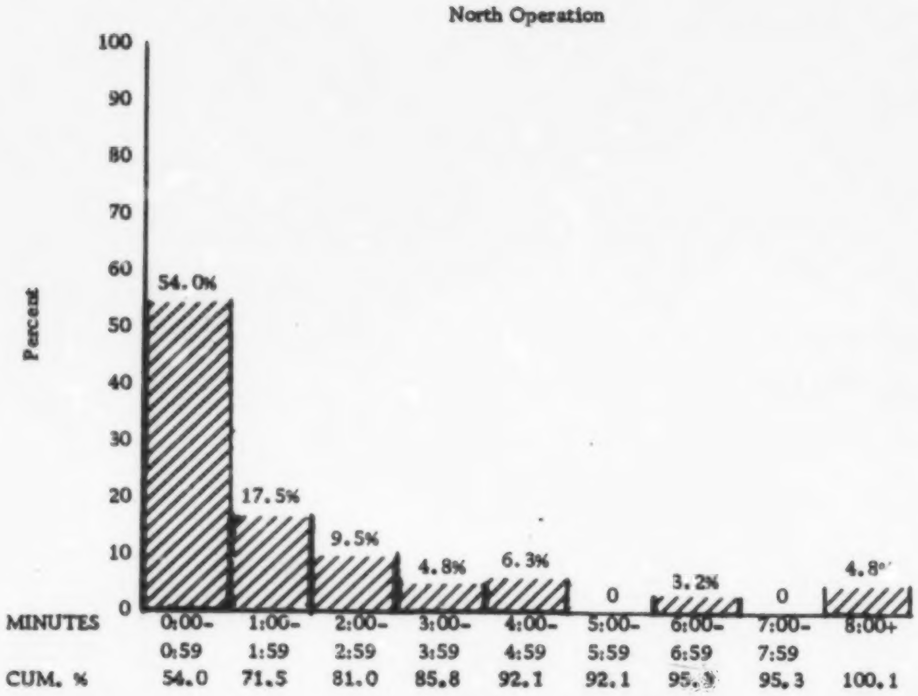

North Operation

Figure 11. Time of Delay at End of Runway

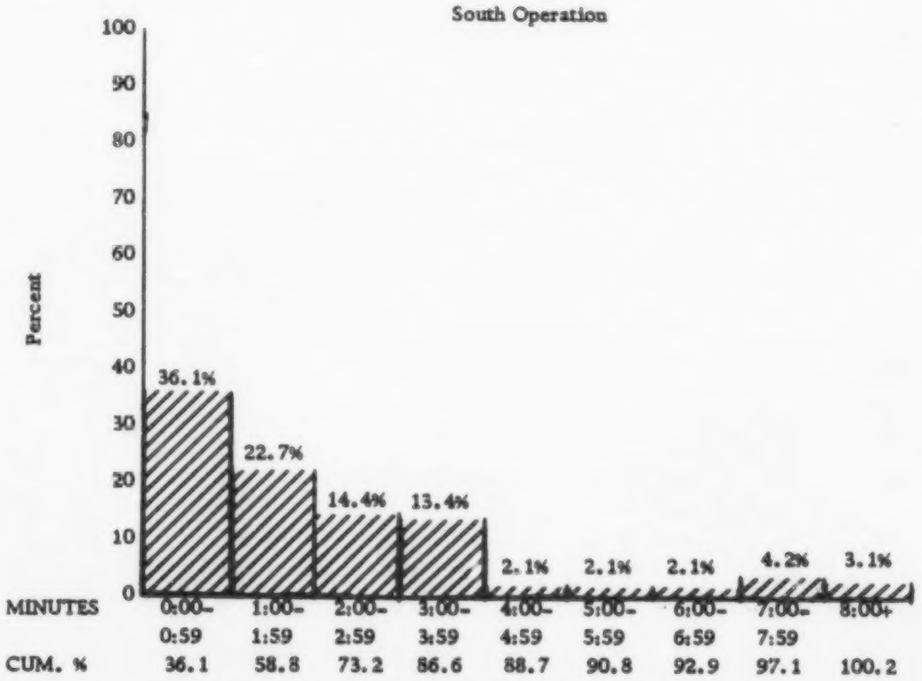

South Operation

Figure 12. Time of Delay at End of Runway

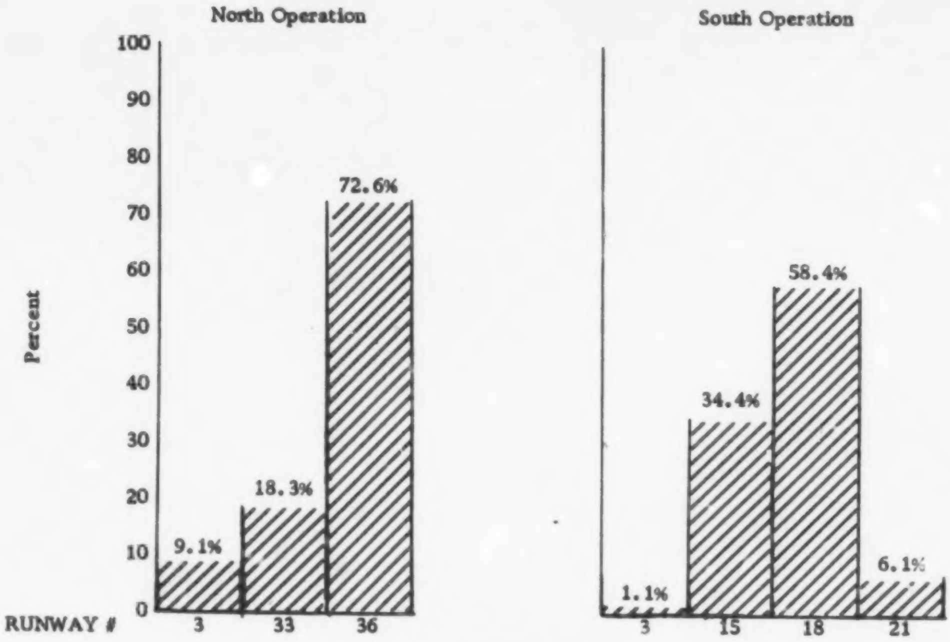


Figure 13. DEPARTURES: Percentage Use of Runways

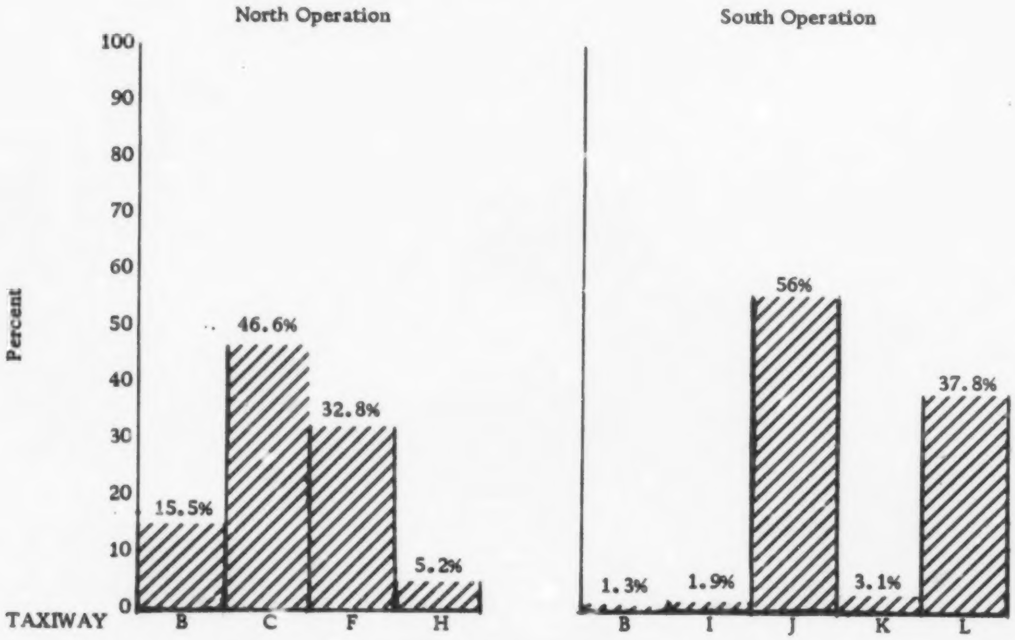


Figure 14. DEPARTURES: Percentage Use of Taxiway

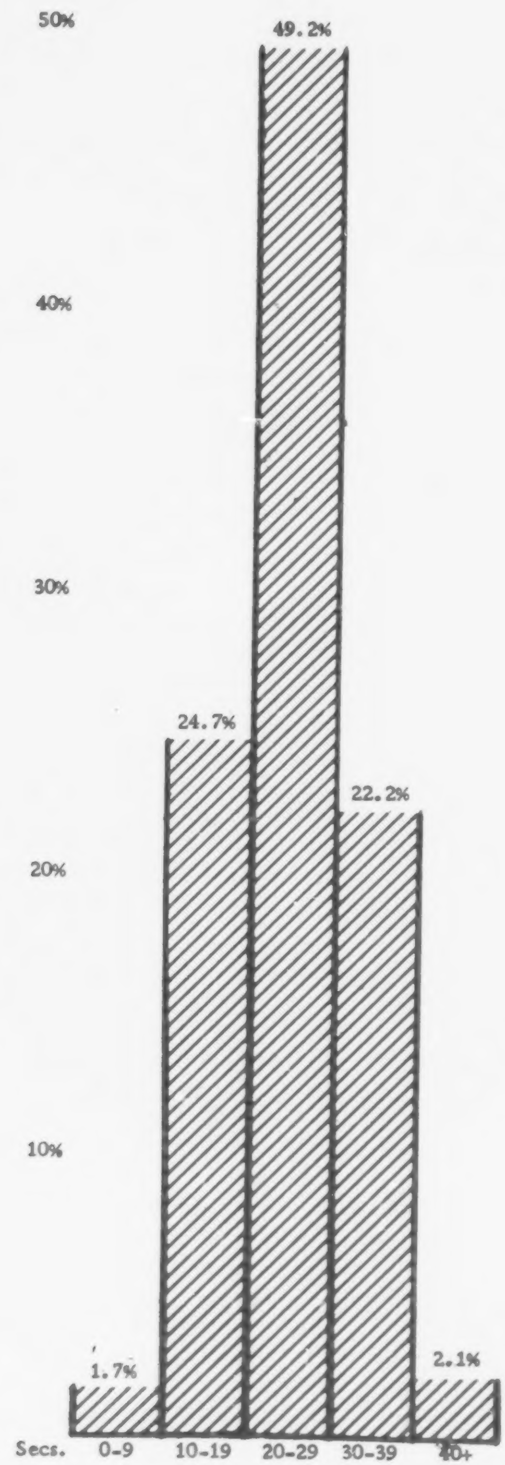


Figure 15. Frequency Distribution of Elapsed Time from Start of Roll to Liftoff.

Taxiing from runway to the gate was an easily distinguishable mode but length of time involved was mostly dictated by the taxiway and gate assignment combination. Figure 4 shows the frequency distribution of arrival taxiing times.

Maneuvering into gate and engine shut down mode was a relatively constant value for all the commercial aircraft observed.

Figure 8 shows the distribution of gate times observed for gate maneuvering.

Auxiliary power units and support vehicle operations vary according to the policies of the airline and depending on whether the flight was originating, terminating or a scheduled stop for a continuing flight, and on type of aircraft. A statistical model of these conditions might be helpful when truly refined model inputs are required.

Engine start-up and maneuvering from gate was dependent on airline policies. Some jet aircraft engines were not started until the aircraft had been pushed back from the gate to the point where they would taxi under their own power. Some jet aircraft would start the engines during the pushback operation. Propeller aircraft with external auxiliary power units (APU) also had varying policies of running some or all engines before and after the APU's were connected or disconnected.

Time for taxi to runway varies according to the gate assignment and the wind direction e.g., an aircraft at a gate in the north terminal must taxi to the south end of the field for take off during northerly winds. Taxiing times for departures during north and south operations are shown in Figures 9 and 10.

The distribution times of duration of delay are shown in Figures 11 and 12.

The take-off mode could only be observed as the duration of time the aircraft turned onto the runway until the wheels lifted off. Those time distributions are shown in Figure 15.

A tabulation of arrivals or departures according to aircraft type determined the distribution to be 64.5% commercial of which 36.5% were 727 or 737 type aircraft and 28% were Electra's, 580's, etc. Arrivals and departure activity involving other aircraft (not scheduled air carrier) accounted for 35.5% of the traffic. Of the 35.5% 25% were propellor driven and 10.5% were jet propelled aircraft.

Data Analysis and Processing

All of the data collected during this study are written on a edited processed data tape. Figure 16 illustrates schematically the flow of data from the field site to the final data tape.

CO data from the strip charts were read from the chart and coded for punching onto IBM cards. The analyst reading the chart visually integrated the area covered by the pentrace over each one hour segment and coded that value.

The particulate data from the Hi-Vols were treated in several steps. First, the net weight of particulates was determined in the laboratory, then the net weight, flow rate and duration of the sample were coded for keypunching. The card data were processed with a program to determine the concentration of particulates and that information stored on disk in the computer until the final data tape was written.

The data collected by the data acquistion system on paper tape were read onto magnetic tape then onto a disk for processing. Processing from the disk included editing out extraneous signals and garbled data then inserting missing indicators where necessary. In some instances when the teletype unit malfunctioned the data were only available on hard copy which made it necessary to keypunch the data onto cards then read the data onto the disk pack. Once all the data were on the disk the editing and conversion from voltage units to concentration units was accomplished.

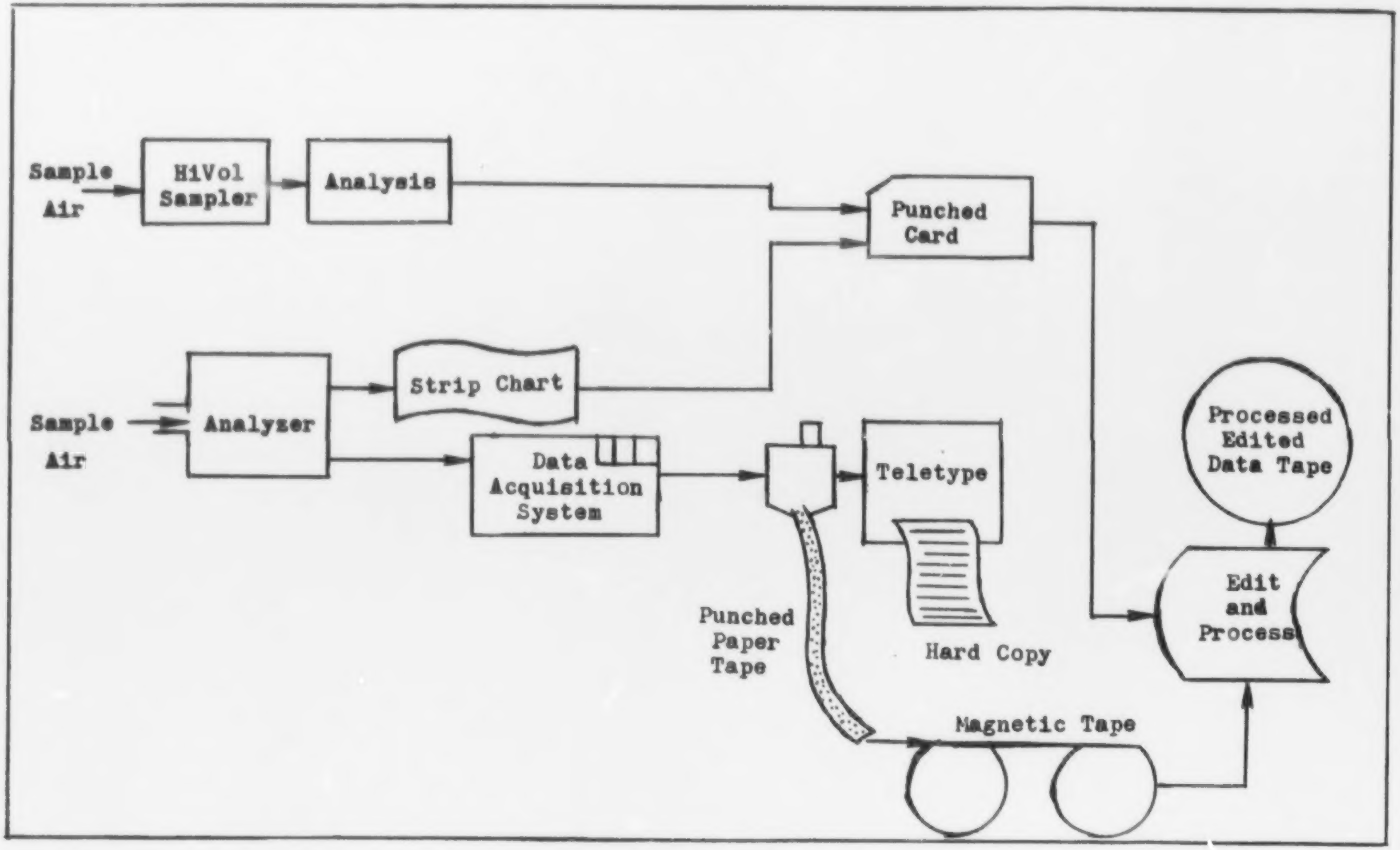


Figure 16. Data Collection and Processing

Data Editing

The data acquisition system used in this program converted and recorded 0.0000- ±1.0000 analog voltages, produced by each instrument, on paper tape and hard copy.

In the interium between calibration the NO_2 Analyzer, Ozone Monitor, and Photometer were subject to several forms of drift. In the case of the NO_2 analyzer there were three forms of drift possible; Electronic which was observed to be linear, Chemical which degenerated fairly linearly, and constant crystaline buildup on the comparison cellwalls. With these linear shifts a program was divised to calculate the actual instrument zero for any day using an averaging technique along a time scale of 3 days bracketing the day in question. For the ozone monitor and UV photometer the only form of applicable drift was electronic. Applying the same method described above the daily zero was calculated. With these zero correction factors we were able to calculate values for the output data of the above mentioned instruments.

Limits were imposed on the data processing program to eliminate erroneous information obtained from malfunctioning instrumentation.

The lower limits due to zero shift were as followes -.0200 for NO_2, -.0100 for O_3, and -.0020 for the photometer. These limits were found to exclude only a fraction of one percent of valid data. The rest of the instrumentation contained built in zero limits automatically referencing all outputs to a real zero.

The following upper limits were established. For the NO_2 Analyzer the upper limit was set at .345ppm which was the highest calibration point. For the O_3 monitor .2ppm hourly and for gas chromatograph 15.00ppm was chosen for CO, CH_4, and THC after studying the valid data. The remaining instruments have a built in maximum of 1.000. The edited processed data tape contents and format are described in Appendix D.

Summary of Air Quality Data

The continuous air quality measurements, recorded on magnetic tape along with the other auxiliary observations for future use, are summarized in distributional and statistical form in Table 8.

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*Here, and elsewhere in this report, Stations 1N (November through January) and 1S (February through April) are referred to as Stations 1 and 8 respectively; this nomenclature was for convenience in computer processing and printout.

Table 8. Air Quality Concentrations Measured at DCA, Monitored During October 1972 through April 1973, As Described in Text

Station	Number	Statistical Parameters of Distributions													
		Mean	Minimum	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	Maximum
1-Hour CO Concentrations, mg/m^3															
1	1321	2.48	0.20	0.50	1.10	1.10	1.70	1.70	2.20	2.80	3.40	4.50	6.20	10.05	19.4
2	1880	1.52	0.08	0.56	0.81	0.94	1.03	1.11	1.18	1.26	1.54	2.85	4.36	9.46	16.3
3	2713	2.10	0.11	0.87	0.98	1.11	1.23	1.42	1.67	2.21	3.39	4.80	5.52	6.26	10.8
4	3975	4.43	0.20	1.10	1.90	2.20	2.80	3.40	4.00	4.60	5.90	8.50	11.4	17.1	60.1
5	4137	2.99	0.10	1.10	1.70	1.70	2.20	2.50	2.80	3.40	4.00	5.16	6.80	9.10	19.4
6	1599	1.52	0.08	0.74	0.85	0.99	1.11	1.28	1.45	1.65	1.95	2.42	3.14	4.86	9.35
7	4061	4.97	0.20	1.10	1.70	2.00	2.20	2.80	3.40	4.00	4.80	6.56	9.10	69.5	88.1
8	1574	1.84	0.20	0.50	0.90	1.10	1.10	1.70	1.70	2.20	2.50	3.40	4.50	6.80	11.4
8-Hour CO Concentrations, mg/m^3 (at least 5 out of 8 obs. available)															
1	293	2.59	0.50	1.09	1.38	1.61	1.89	2.14	2.45	2.80	3.43	4.88	5.41	9.97	12.0
2	428	1.52	0.18	0.62	0.90	0.97	1.02	1.12	1.18	1.26	1.67	2.95	3.68	9.33	9.63
3	619	2.10	0.12	0.90	1.06	1.18	1.31	1.45	1.74	2.21	3.42	4.75	5.25	5.74	7.06
4	923	4.50	0.50	1.89	2.51	2.95	3.40	3.84	4.33	5.04	6.04	8.04	9.75	12.8	21.6
5	1004	3.02	0.58	1.43	1.75	2.05	2.36	2.66	3.04	3.41	3.90	4.95	6.05	7.76	13.6
6	381	1.53	0.52	0.82	0.91	1.03	1.16	1.33	1.51	1.67	1.89	2.40	3.23	4.44	7.29
7	920	5.18	0.36	1.45	1.91	2.39	2.74	3.16	3.60	4.09	4.88	6.19	7.84	70.0	83.3
8	352	1.87	0.28	0.68	1.00	1.15	1.35	1.64	1.87	2.14	2.53	3.26	4.37	6.10	8.10
1-Hour Non-Methane Hydrocarbon Concentrations, $\mu g/m^3$															
2	1922	1258	0.54	91.5	250	353	483	655	863	1152	1733	3315	4991	7788	9564
3	2129	321	1.64	30.4	57.2	97.0	127	166	205	259	374	1019	1233	1828	4440
6	1606	1206	18.0	377	776	967	1108	1238	1337	1435	1570	1818	2069	2461	4813

(Continued)

Table 8. Air Quality Concentrations Measured at DCA, Monitored During October 1972 through April 1973, As Described in Text (Concluded)

Station	Number	Statistical Parameters of Distributions													
		Mean	Minimum	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	Maximum
6-9 a. m. Non-Methane Hydrocarbon Concentrations, $\mu g/m^3$ (at least 2 out of 3 obs. available)															
2	104	983	0.0	0.0	50.8	195	303	465	599	788	1275	2518	4736	8677	9063
3	73	320	0.0	0.0	13.4	37.4	88.7	111	133	196	348	1173	1708	2552	2934
6	28	1187	342	482	927	1094	1136	1229	1308	1438	1546	1873	1959	1974	1974
1-Hour Nitrogen Dioxide Concentrations, mg/m^3															
2	3489	180	2.18	49.6	73.0	93.8	114	145	180	220	286	378	432	488	631
3	3214	149	1.73	34.1	55.2	68.7	84.0	104	137	172	221	330	454	546	639
6	2040	127	0.38	27.5	42.3	57.2	70.6	89.6	111	164	210	270	348	427	623
24-Hour Particulate Concentrations, $\mu g/m^3$															
1	77	66.4	32.9	42.0	47.3	51.6	57.5	62.8	66.5	78.1	88.1	99.6	114	130	141
2	170	88.3	29.2	47.4	57.9	65.5	74.6	81.9	92.8	108	117	134	148	180	272
3	149	54.2	7.9	34.1	39.3	42.2	46.9	51.1	55.6	60.5	69.9	79.1	91.5	105	144
4	166	97.9	38.4	58.9	70.6	78.6	86.6	93.7	105	113	127	140	151	180	193
5	176	77.1	26.0	45.3	51.4	58.2	67.0	73.6	80.9	93.1	101	112	[illegible]	149	159
6	150	68.9	18.5	39.9	47.1	56.6	60.2	64.9	70.1	74.7	82.3	100	[illegible]	137	267
7	156	130	21.1	57.5	72.1	87.4	105	128	137	154	176	218	[illegible]	286	436
8	85	65.6	24.7	39.6	45.3	50.9	56.6	63.1	70.1	75.6	83.8	97.0	[illegible]	126	132

SECTION V

THE NREC MODEL, THE MODIFIED MODEL, AND THEIR VALIDATION

THE NREC MODEL

Description

Since the NREC model plays two roles in this project it is appropriate to provide a description of the model and its use. This is done briefly in the following discussion, adapted from Volume 1 of the NREC report*, and in Appendix E, which is quoted from Volume 2 of that report* and gives details of the computer program.

The two roles of the original NREC model in this project are (1) to be verified against a sufficient sample of air quality observations to establish its baseline validity (this is reported in the Section titled The NREC Model Compared to the Dependent Data Sample) and (2) to be used as the base model on which additions and modifications were to be implemented for the required improved model (reported in the Section titled The Modified Model).

The model can be usefully considered in two parts: an emissions model, which accepts emissions as input and distributes them in space and time as appropriate, or which accepts operational descriptions of aircraft and/or automotive activity and converts them into similarly distributed emissions; and a dispersion model, where these emissions are then used, together with the appropriate meteorological inputs, for the calculations of pollutant concentrations in and near the airport. Either or both of the emission distributions and the concentrations may be printed out in a variety of ways to analyze and study many facets of airport air pollution.

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*Platt, et al., 1971.

Following are quotes from the NREC report:

"Emissions at an airport are modeled by a large number of continuous point sources of constant strength which are distributed throughout the airport and its surroundings. The sources are located in the following manner:

1. Aircraft emissions during the start-up and idle, and idle and shutdown modes at the terminals.
2. Aircraft emissions during the taxi mode at stations which divide each taxiway into a number of equal segments.
3. Aircraft emissions during the delay-at-runway mode at the heads of the runways.
4. Aircraft emissions during the landing and take-off modes at stations which divide each runway into a number of equal segments.
5. Aircraft emissions during the approach and climb-out modes at stations which divide a single approach and climb-out path for each runway into a number of segments which become successively larger as distance from the airport increases.
6. Aircraft emissions during the fuel-venting mode at a single point on the climb-out path of each runway.
7. Aircraft emissions during the maintenance mode at the hangars.
8. Motor vehicle emissions at stations which divide each roadway (including the parking areas) into a number of equal segments.
9. Heating plant emissions at the heating plants.
10. Fuel storage emissions at a point within each storage area.
11. Surrounding area emissions at a point within each subdivision of the surroundings.

The strength of each point source of emissions is calculated from the emission factors and airport characteristics provided as input data.

The basis of the modeling of atmospheric dispersion is the empirical double-Guassian plume solution to the diffusion equation. The solution is for a steady-state continuous point source in a wind of non-zero magnitude. The plume spread in the vertical and crosswind directions is Gaussian in form and is dependent upon downwind distance from the source and atmospheric stability. Eventually the trapping effect of the upper limit to vertical mixing (the mixing height) restricts the vertical plume spread and modifies the solution. In the calculation of short-term concentrations, this dispersion model is applied to a single set of meteorological conditions. In the calculation of long-term concentrations, the fact that there is a distribution of meteorological conditions is used to simplify the basic dispersion model. The result, known as the Martin-Tikvart model, approximates plume spread in the crosswind direction and sums the contributions of all combinations of wind speeds and atmospheric stabilities.

The concentration at any receptor point is obtained as the sum of the contributions from each point source of emissions. The representation of a line or area emission source at an airport by one or a number of point sources results in inaccuracies which increase with proximity to the sources. The magnitude of the inaccuracy for a specified distance between receptor and source point depends on the physical dimensions of the actual source."

Implementation of the NREC Model for use in the Present Project

Our implementation follows the original NREC implementation with three exceptions: first, we have corrected minor errors and made some modest improvements in the printout display. Second, and far more important the NREC employment of the model for short-term concentrations involves the input of a single wind direction, and also a representation of the wind direction variability superimposed on the primary direction. In our judgement, the use of dispersion parameters which were developed from diffusion data measured over periods of the order of an hour already includes the appropriate wind direction variability for any given stability class, so that the superposition of further wind direction variability is unnecessary and implies excessive dispersion. Accordingly, we have used a single direction value only, in all NREC model calculations (as well as in all calculations with modified versions of the model). This represents a basic difference in our use of the NREC model, and has the obvious implication that our employment will always generate higher concentrations than will the model as it was used by NREC, and as we understand it has been used subsequently by NREC and Argonne National Laboratories in more recent contract programs for the FAA (Zimmerman, 1972).

The third exception to NREC's implementation is in the area of calculation of long term concentrations. As described in the previous section, NREC has an option which employs the joint frequency distribution of meteorological conditions together with the emissions distribution for this purpose. Problems associated with this approach have been demonstrated in other projects (Koch and Thayer, 1972, Koch and Fisher, 1973); the problems arise because the approach assumes independence of meteorology and emissions, which often does not hold. This will particularly be the case when the emissions have a significant diurnal variation, as is the case with aircraft and automotive activity.

Our preferred mode for developing long term values is by the use of a concept developed in the above cited projects, that of generating such information by calculating a sufficiently large number of the single short-term values which go to make up the long-term concentrations. Accordingly, all of our tests and implementations involve calculation of one or more short-term (in all cases, one hour) concentration values.

This procedure has the further advantage of minimizing another problem which arises in the way NREC implemented the model for the calculation of short-term maximum values. In that report, judgment is used to select the combination of meteorological conditions . . . "from observations of hourly meteorological data to represent the maximum potential for pollutant concentrations." There are potential risks in this procedure for determining when maxima will occur (e.g., it does not ensure that the maximum has been identified; further, it implies that the occurrence of the maximum is a function of meteorological conditions alone and does not consider the interaction with emissions). There is even the risk that the "maximum" thus identified will be so low as to be less than the associated mean value, an obvious impossibility. The occurrence of such a combination of events is demonstrated frequently in the calculations of the NREC report. For example, their Tables 57 and 68a and b, show that this occurs for the mean and maximum values for: particulates at receptor points 31, 44 and 45; NO_2 at point 44; and SO_2 at point 21. For SO_2 there also occur frequent cases where this procedure gives a 24-hour maximum value which is higher than the 3-hour calculated maximum, also impossible in reality. There are similarly numerous cases where the calculated 8-hour CO maximum exceeds the 1-hour maximum. Examples of this are given in our Table 9, extracted from the calculations for DCA in the NREC report. They sited receptor points for calculation purposes as follows: numbers 1 through 28 are on and immediately adjacent to the airport proper; and numbers 31 through 46 are located in the surrounding environs of the airport, on the circumference of a circle of approximately 5 km in radius.

When the distribution is generated by calculating all short-term values, or a statistically acceptable fraction of them (Koch and Fisher, 1973), then the variations in emissions and meteorology are recognized, and the risk of missing the maximum is considerably lessened. This has been the procedure employed for all calculations in this project, for both NREC and modified models, and is our recommended procedure for normal use.

Table 9. EXAMPLES OF CALCULATED AVERAGE AND MAXIMUM CONCENTRATIONS FROM THE NREC REPORT, IN WHICH A MAXIMUM IS CALCULATED TO BE LESS THAN THE ANNUAL AVERAGE, OR THAN A LONGER PERIOD MAXIMUM

Receptor Number	Calculated Particulate Concentrations, $\mu g/m^3$			
	Annual Average		24-hour Maximum	
	Aircraft	Total	Aircraft	Total
31	1.4	21	0.0	3.7
44	0.4	13	0.0	1.1
45	0.4	17	0.0	8.3

	Calculated NO_2 Concentrations, $\mu g/m^3$			
	Annual Average		24-hour Maximum	
	Aircraft	Total	Aircraft	Total
44	0.6	36	0.0	5.0

	Calculated SO_2 Concentrations, $\mu g/m^3$			
	Annual Average		3-hour Maximum	
	Aircraft	Total	Aircraft	Total
21	0.9	25	0.0	6.5

	Calculated SO_2 Concentrations, $\mu g/m^3$			
	24-hour Maximum		3-hour Maximum	
	Aircraft	Total	Aircraft	Total
8	7.1	320	0.0	170
20	4.6	210	0.0	53
21	3.1	140	0.0	6.5
33	0.0	240	0.0	140
34	0.0	260	0.0	58
35	0.1	330	7.8	320
37	0.8	110	0.5	38
39	0.5	67	0.0	40
42	0.1	32	0.0	0.0
43	0.0	33	0.0	0.0
45	0.0	10	0.0	0.0
46	0.0	80	0.0	0.0

THE MODEL AS MODIFIED IN THIS PROJECT

The model modifications implemented in this project, and intended to improve its predictive capability (limited evidence prior to this project had indicated a significant tendency to underpredict), arose from suggestions in the NREC report, recommendations in the contract work statement, and from studies and analyses conducted during the course of this project.

In general terms the modifications represent improvements in the operational reality and detail of the modeling of various categories of emission sources, the inclusion of additional significant emission sources, and improvement in the applicability of emission parameter values. One may also choose to consider that the changes in model implementation described in the Section titled Implementation of the NREC Model for use in the Present Project represent modifications; in any event, they generate significant improvements in the basic NREC model's predictive capability.

Each principal modification, and its implementation and input data, is described in the following sections. Further detail and the results of special analyses of incremental effects of certain modifications may be found in Appendix H.

Aircraft Classifications

The revised classification system* for aircraft is given in Table 10. The basic principle is to group aircraft which have the same numbers of engines of like types and similar models, in contrast to the previous scheme of NREC which grouped aircraft according to type, i.e., Jumbo Jet Transport, Long-Range Jet Transport, Medium-Range Jet Transport, Turboprop Transport, Business Jet, etc. Since the latter approach groups aircraft with different numbers of engines in certain of the categories, resulting in the assignment of a fractional number of engines to that

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* The material in this section, and the next one on aircraft operational modes and emissions, was developed under a consulting arrangement with GEOMET by Dr. E. Karl Bastress, formerly of NREC and now with A.D. Little, Inc. of Cambridge, Mass. These emissions data are now contained in EPA's AP-42 publication on recommended emission rate data.

Table 10. REVISED AIRCRAFT CLASSIFICATION

Class	Aircraft
A	B747
B	DC10, L-1011
C1	B707 - 120B, B707 - 320B B720B, DC8 - 50, DC8 - 61, VC10
C2	B707 - 120, B720
C3	DC8 - 20
C4	CONV. 880
D	B727 - 100, B727 - 200
E1	DC9 - 10, DC9 - 30, B737 - 100
E2	BAC 111 - 200, AEROSP. SE 210 (CARAVELLE)
F	L - 188A (ELECTRA)
G	CONV. 580
H	NAMC YS11, F - 27, FH - 227, N262
I	BEECH 99, DHC TWIN OTTER
J1,2	Piston Engine Utility (by number of engines)

Note: Classes with a common letter designation, i.e., C and E, include aircraft with similar emission and performance characteristics.

category (e.g., 2.6, 2.5), based presumably on a relative frequency of occurrence, it is considered preferable to categorize by integer numbers of engines. Table 11 presents a comparison in which the significant differences are seen, as represented in the GEOMET system (focusing number and type of engines and grouping engine types with similar emissions), and the NREC system, which emphasizes aircraft category (jumbo jet transport, turboprop transport, etc.). Contrast, for example, GEOMET's A and B with NREC's 2; D and E with 4; and F and H, with 5. The table is exemplary only, does not contain all classes and aircraft types, and is intended primarily to contrast the principal differences between classification systems.

Table 11. Contrast Between the GEOMET and NREC Aircraft Classification Systems

Aircraft		NREC		GEOMET	
Type	Engines (No. & Type)	Classi-fication	Engines per A/C*	Classi-fication	Engines per A/C*
Boeing 747	Four JT9D	2	4	A	4
Douglas DC-10	Three CF6	2	4	B	3
Boeing 707	Four JT3D	3	4	C	4
Douglas DC-8	Four JT3D	3	4	C	4
Boeing 727	Three JT8D	4	2.6	D	3
Douglas DC-9	Two JT8D	4	2.6	E	2
Lockheed Electra	Four 501-D13	5	2.5	F	4
FH-227	Two Dart	5	2.5	H	2

*According to Classification Scheme

Aircraft Operational Modes and Emissions

The aircraft operational modes are selected to physically represent significant operational phases and permit assignment of proper emission rates to them. The model assignments are made by aircraft class, since the operational and emission characteristics within each class are sufficiently similar to permit such treatment. Further, the basic operational profiles among all aircraft are sufficiently similar, at least for the purposes of this project, to permit use of the same profile for all aircraft, with real differences accounted for in variations in the input operational parameters and emission rates.

The operational and emission parameters which resulted from the analysis of this portion of the project are given in Appendix F.

Details of Airport Representation

Analysis of the representation of the Washington National Airport structure, as it had been handled in the NREC study, led us to the conclusion that an increase in level of operational realism and detail was needed for the runways, taxiways, terminals and employee roads and parking. The depiction as it is in NREC is seen in Figure 17, and in the expanded form of the modified model in Figure 18.

In this modification, the terminals (gates) and taxiways are increased in number in order to distribute the aircraft activity in a more representative way geographically; the terminal activity is augmented by the inclusion of aircraft auxiliary power units (APU's) and aircraft service vehicles, which were not included in the original NREC model (although the capability of the model to include them was considered). In addition, an active employees' parking lot in the vicinity of receptor Station 7 was added to account for the extra automobile traffic in that area.

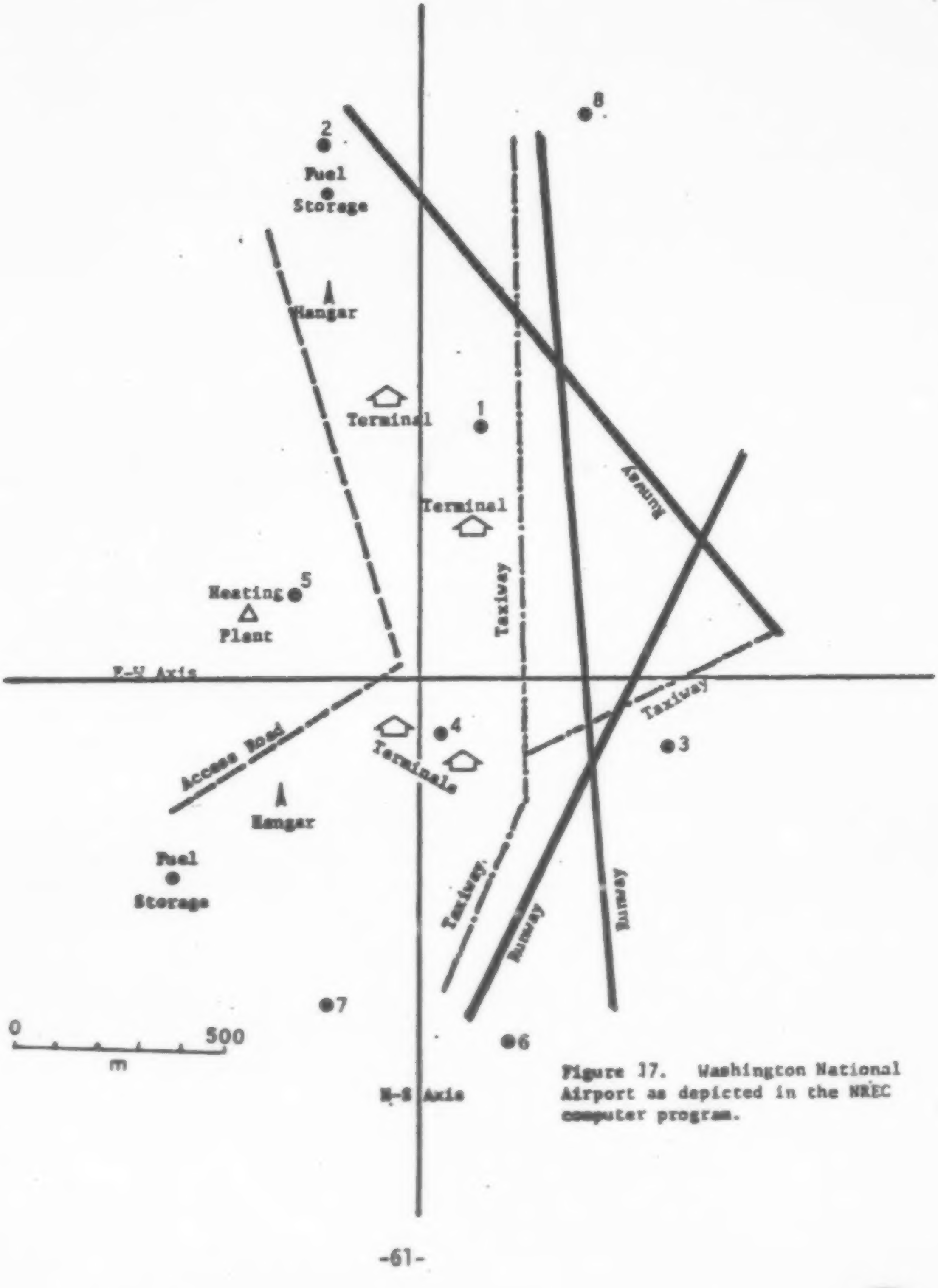


Figure 17. Washington National Airport as depicted in the NREC computer program.

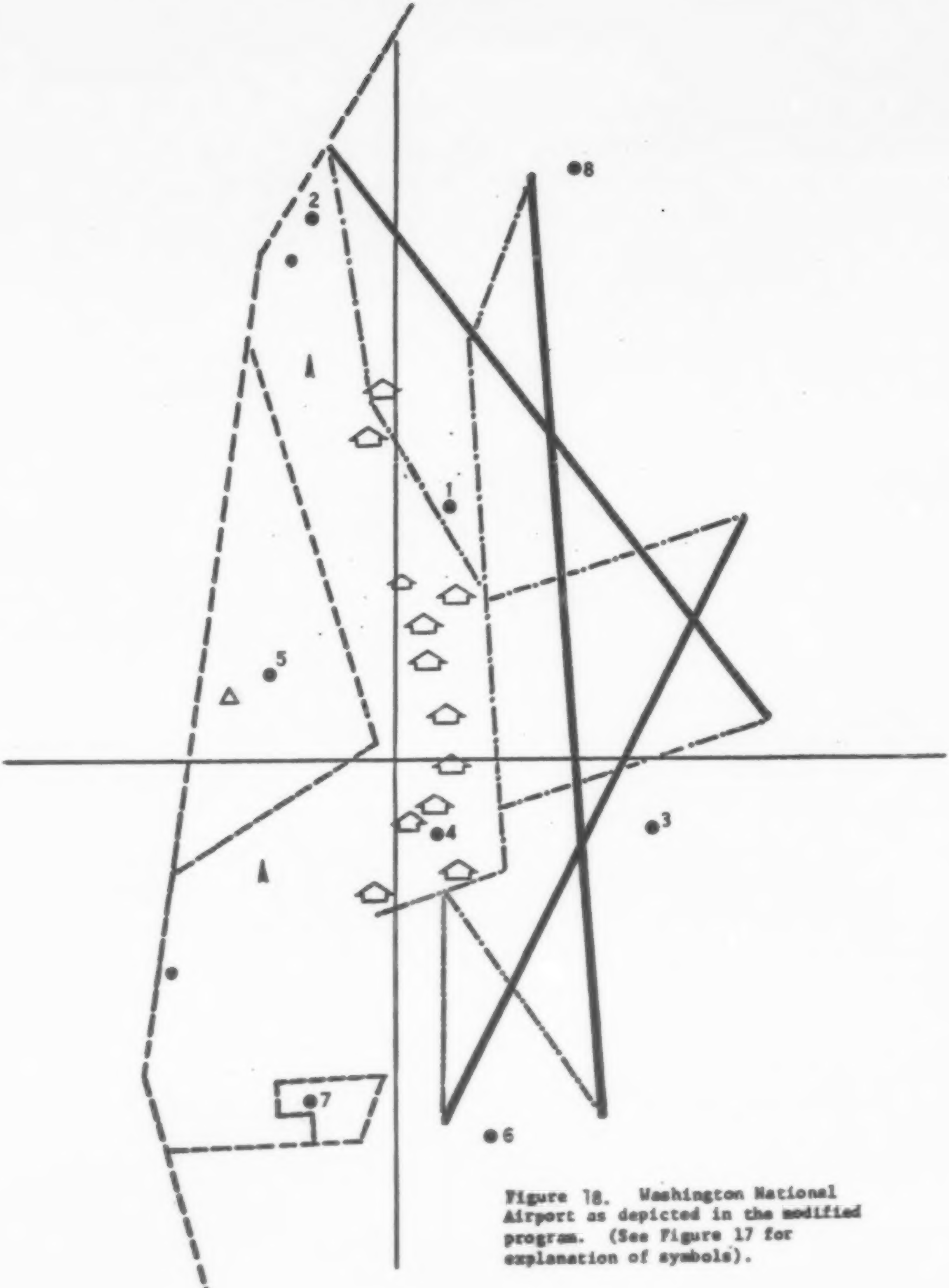


Figure 18. Washington National Airport as depicted in the modified program. (See Figure 17 for explanation of symbols).

Environ Area Source Modeling

Of the techniques available to more nearly represent the environs of the airport as true areas, the simplest, and the one using the least computer time, turned out to be the one which involved simply increasing the number of points representing the areas by a factor which was sufficient, yet not excessive, and dividing the area source emissions correspondingly among the new points, considering both the geography and the distribution of "Implementation Plan" area emissions data described in the next section.

Experiments with different numbers of points are discussed in Appendix H; in the final model, the 16 points used in NREC were increased to 64, with satisfactory results.

Environ Area Source Emission Data

The basic NREC model uses, for its description of emissions from the environ area sources, characteristic emission factors derived by EPA from St. Louis data for area emissions. These are described as city, urban, suburban, etc. We sought out data more explicitly related to the Washington, D.C., area, and found this in the data prepared for the EPA-required Implementation Plans. These data for each pollutant of interest were interpreted into terms which are useable as input to the program. They were employed in two ways; first, the specific computer inputs in gm/sec/km^2 are directly comparable for each pollutant. Study of the pairs of area pollutant emission assignments compares the emissions using standard factors with those from updated implementation plan (IP) factors, for the fifteen NREC area segments (Figure 19) for four pollutants (carbon monoxide, nitrogen dioxide, particulates, and hydrocarbons) (Figures 20 through 23). There is a satisfying degree of agreement in the majority of the cases, but a few rather extreme descrepancies are seen.

The final modified model employs the IP emission inventory data for the area source emission rates.

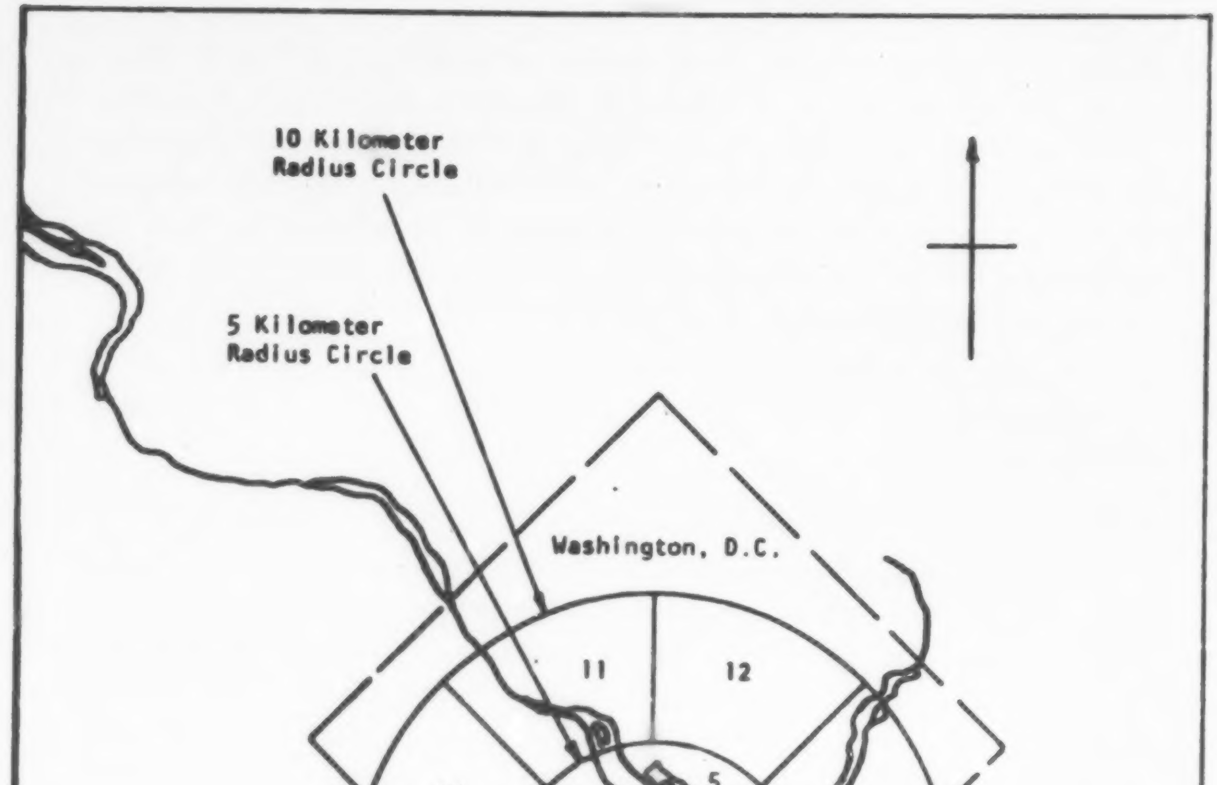


Figure 19. Classification of Surroundings of Washington National Airport.

Figure 20. Comparison of Carbon Monoxide Emission Factors

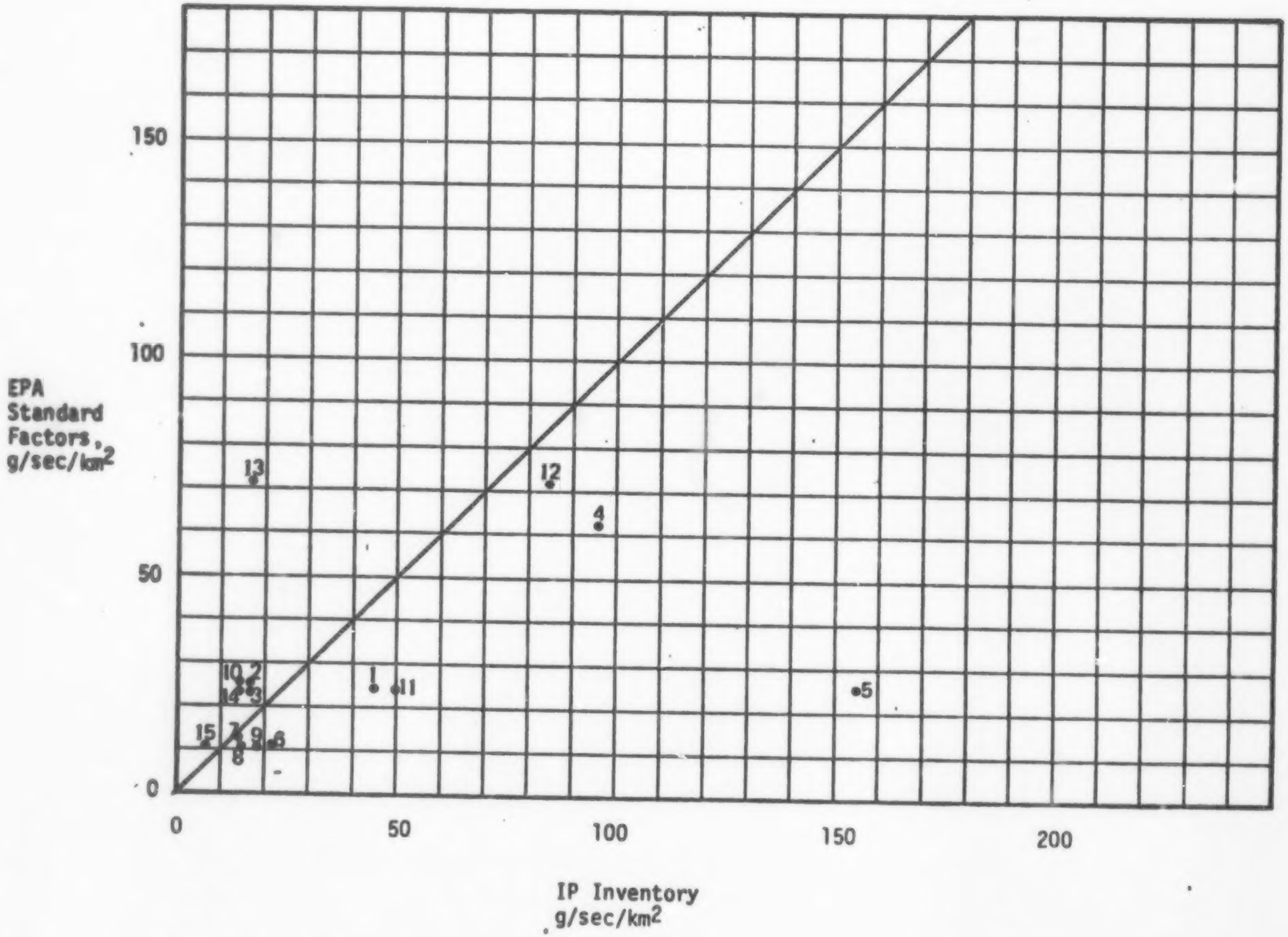


Figure 21. Comparison of Nitrogen Dioxide Emission Factors

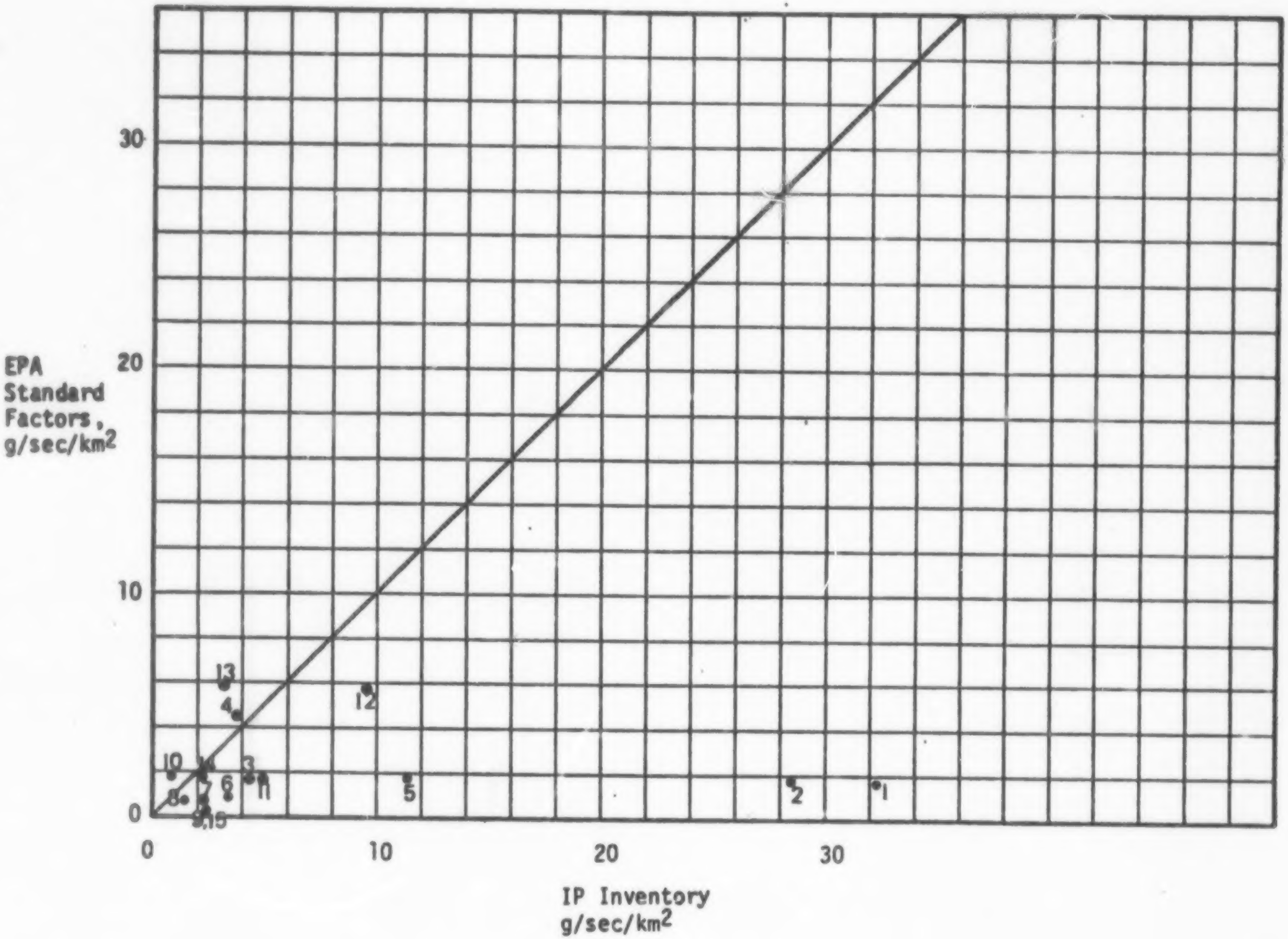


Figure 22. Comparison of Particulates Emission Factors

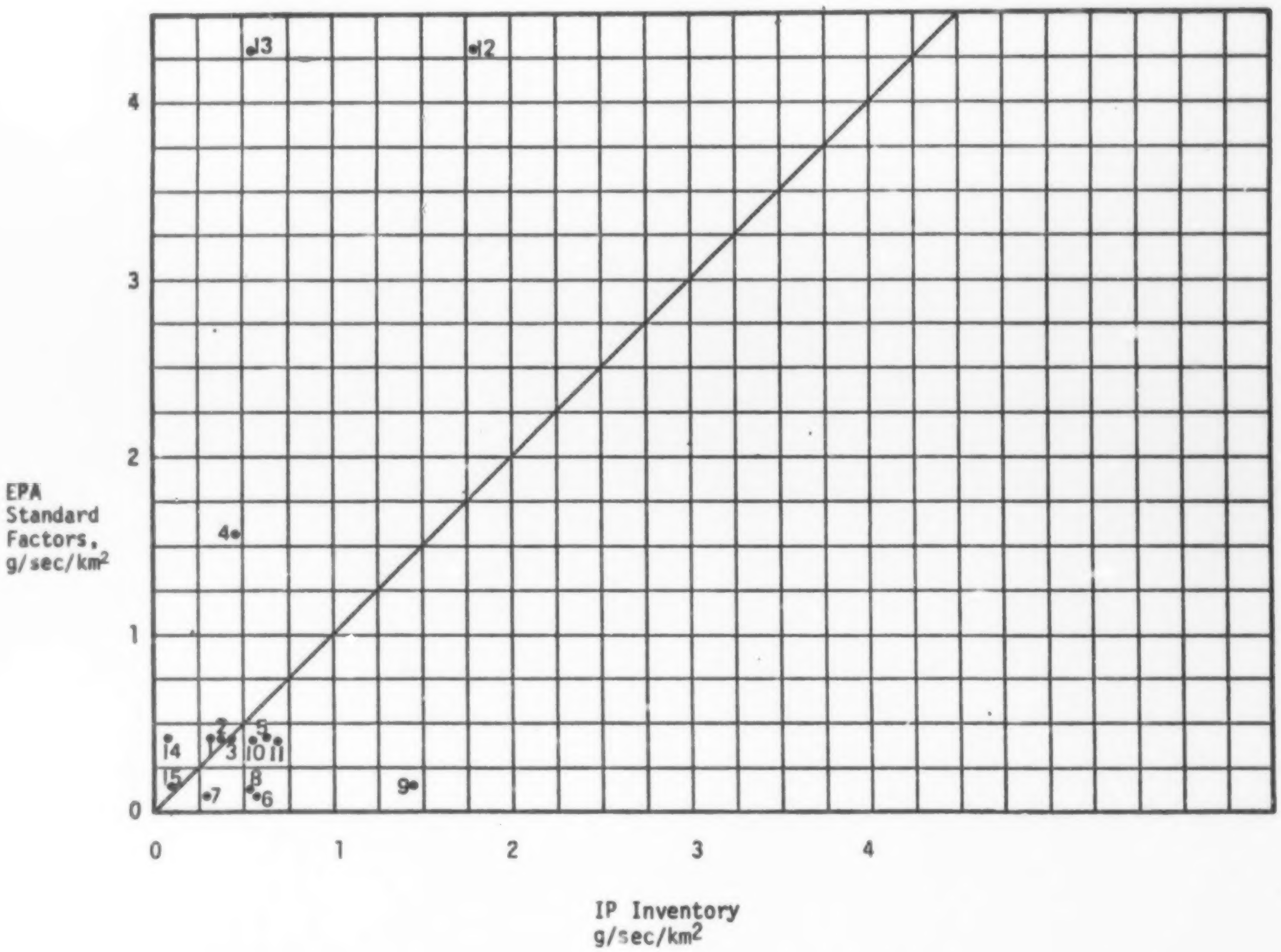
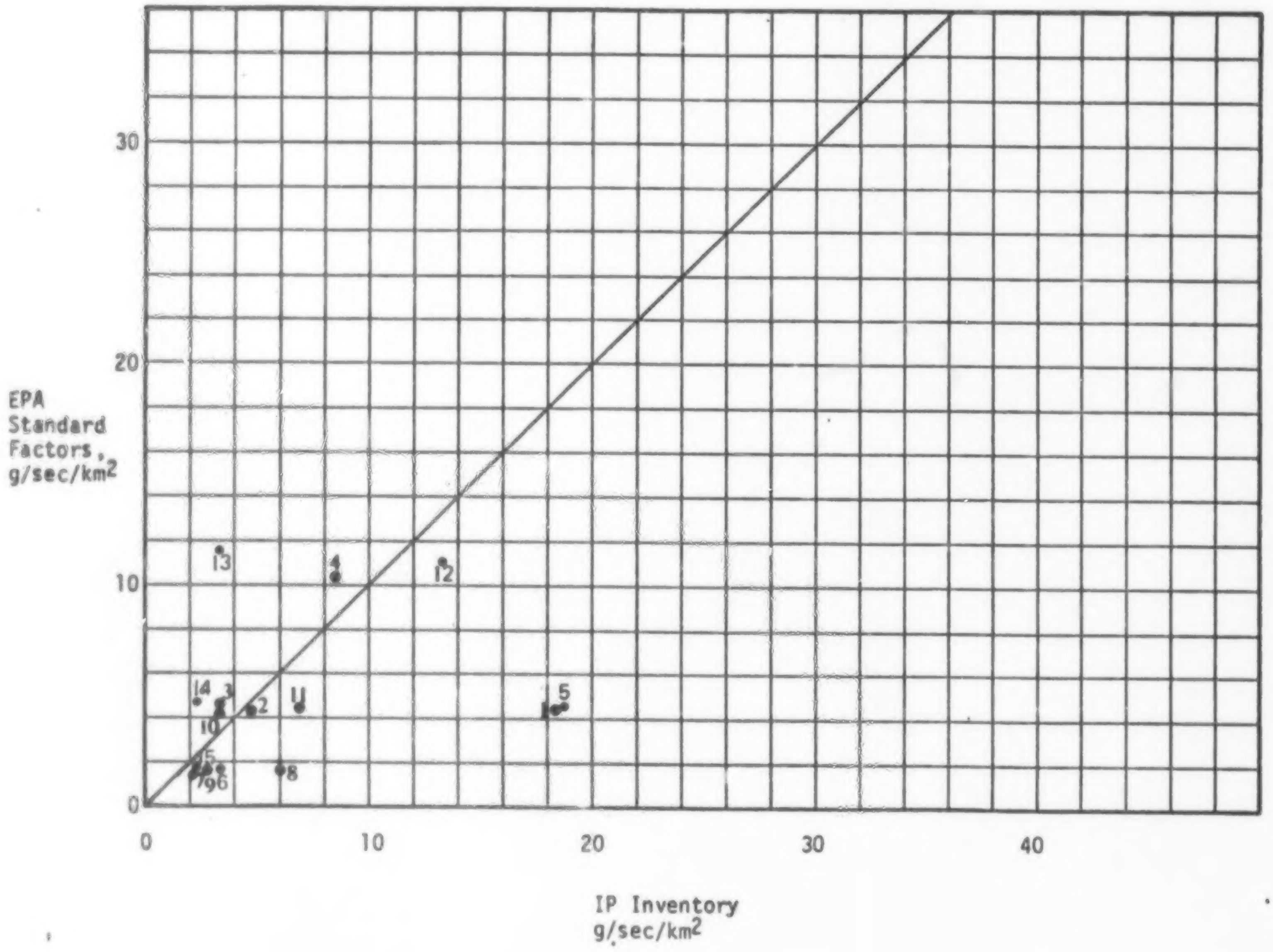


Figure 23. Comparison of Hydrocarbons Emission Factors



Uniform Line Sources

NREC employs, as an approximation to a uniform line source, a small number of points spaced uniformly along the line (runway, taxiway, or roadway). It was generally recognized that improvement was warranted here, at the very least by increasing the number of points; another available alternative was a close approximation to a true line source which has been used in automotive source modeling by the Government Project Officer on this contract. This line source module subdivides the line iteratively into smaller and smaller segments, assigns the emissions into equal shares at points at the segment centers, and tests iterative calculation concentrations until the result is within a small percent (say, 0.5, or 2) of the previous one. Tests showed that differences (between the small number of points of NREC and the uniform line approximation) of factors of three could be found as far downwind as one kilometer, and up to 25% differences at two kilometers.

It was thus obvious that improvement had to be made. Our plan was to use the iterative technique, and that procedure is included as a computer option for all line sources. We were forced to compromise, however, in our final large-scale production runs, because the cost of the iterative technique, while modest for normal usage, would have been prohibitive in the massive number of runs required for validation. Accordingly, we used the results of the tests mentioned above, combined with judgement and the line source-to-receptor distances, to determine a fixed number of points for each line of concern; more points are used on closer-in lines, and in all cases the numbers of points are many times larger than in NREC, so that the results are not judged to be adversely affected. Additionally, the single fixed number we used represented a significant cost reduction over the iterative technique, and so was our choice, at least for this purpose.

Major Peripheral Highways

Another major parameter, which was recognized as potentially needing attention in the previous work, is the inclusion of the emissions from major traffic arteries which surround the airport being studied. To include this we studied traffic data (from Washington Council of Government survey reports, and recent traffic surveys by appropriate local governments) and determined the major peripheral arteries and their daily and diurnal (hourly) variations. Their geographic locations are identified as: the Woodrow Wilson Bridge, the George Washington Parkway and Jefferson Davis Highway (combined), the 14th Street Bridge, the Inner Loop Freeway, South Capitol Street, and the Anacostia freeway; also the Shirley Highway to the southwest from the 14th Street Bridge vicinity (Figure 24). We input their geographic locations and the NREC automotive emission factors (confirmed as matching the recommended EPA factors), along with the diurnal traffic density variations, to develop appropriate automotive emissions in the model.

As a matter of interest, the tests referred to in the Section titled Uniform Line Sources indicated that with vehicle densities as indicated in our succeeding Section titled Sample Effects of Selected Model Modifications, which means about 8000 per hour during the peak hours, the highway influence is significant (of the order of ten to twenty percent of the total concentration) from sources as far as three to five kilometers distant.

The Name

Finally, we have found it necessary to identify the model for convenience, and have been unable to come up with a descriptive name and/or acronym which is simple and appropriate. Following an apparently growing EPA custom which identifies a model by its individual or corporate developer (viz., NREC, S^3, etc.), we have called this one by the explicit name of the EPA-GEOMET Airport model. For convenience, in the remainder of the report we will refer to it as the GEOMET model (just as we call its EPA-sponsored predecessor the NREC model).

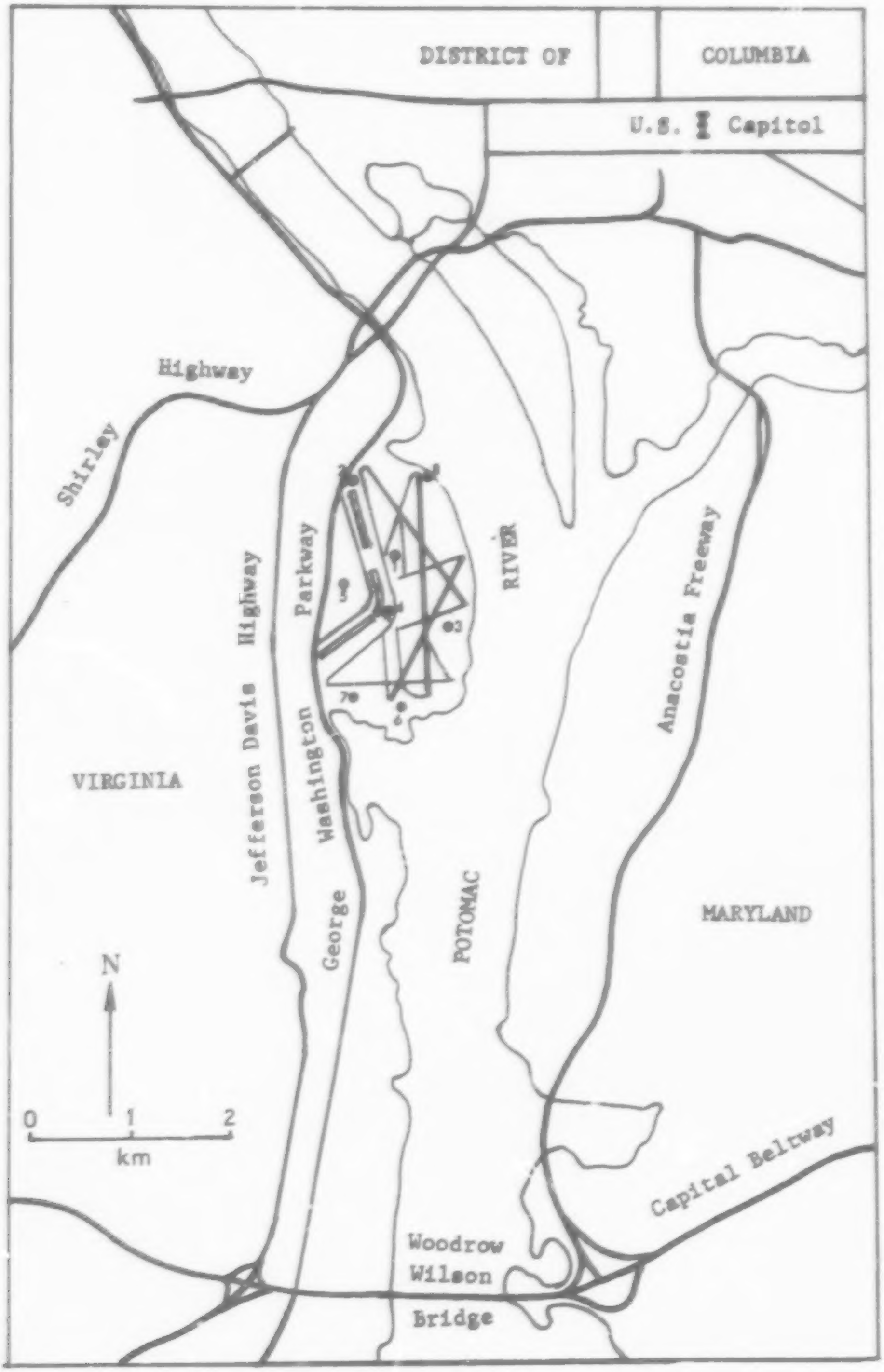


Figure 24. Schematic Representation of Washington National Airport (Center) and its Environs

VALIDATION

Model Constraints

Two facets of both the NREC and the modified (GEOMET) model should be borne in mind in studying the validation results which follow. First, the steady-state Gaussian plume diffusion model which is the kernel of the concentration calculation, and assumes steady conditions during the period of calculation (in this case one hour), is characteristically not expected to give good results when compared to observations on a paired-comparison, hour-by-hour basis. Such a model, when performing well, will reproduce distributions and means to a reasonable degree, and thus will be highly useful for most purposes, including those of making comparisons with standards, and studying the impact of various types of contributing sources, as intended here. It is thus in the latter context that the validation results which follow should be viewed.

Second, while validation comparisons are made for all pollutants of particular interest in this section(CO, NO_2, non-methane hydrocarbons (NMHC) and particulates), neither the NREC nor the GEOMET models are designed to account for the special considerations, and the reactions that occur in the atmosphere, in the cases of NO_2* and the non-methane hydrocarbons**. Thus the results obtained in those validation cases are of uncertain utility as yet. Inferences may be drawn, but there are too many unknowns to justify much in the way of analysis. Hence, the greater emphasis is laid on the validation, interpretation and use of carbon monoxide and particulate*** predictions.

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* Since only NO_2 was required to be measured, validation of NO_x emissions against NO_2 data perforce assumes that all the NO_x is NO_2 at the time and place of sampling. Thus if the model validates with CO and particulates (and thus appears basically sound), and then also validates against NO_2, one could infer that all the NO_x is in fact NO_2. If any NO_x is in the form of NO, then the model should be expected to overpredict correspondingly.

** The non-methane hydrocarbon measurement involves measurement of total hydrocarbons and methane, and subtraction of the latter from the former; this recognizes both the absence of a deleterious pollution effect from methane, and the fact that most often the majority of the methane found in the atmosphere is of natural origin, or non-anthropogenic. If any of the methane subtracted is anthropogenic, the calculation will overpredict as a result of using total hydrocarbon values for emission sources, and subtracting all methane from the observations.

*** In the case of particulates, a natural background exists which must be added to the predicted values. For the Washington, D.C., area, this background value has been generally accepted as about 30 μg/cu.m. for a 24-hour average.

A final comment: a complete series of statistical tests was programmed initially, and has been applied to validations throughout the program. These variously address correlation and regression analysis, paired comparisons, rank order comparisons, tests of means, and so on. Descriptions of these tests, and information about their interpretation are given in Appendix G .

The Dependent Data Sample

All comparisons of NREC, or modified NREC, models with observations were carried out by selecting adequate samples of the relevant pollutant observations for comparison, and by using the corresponding input data (meteorological and aircraft activity) to generate the appropriate predictions.

All input data were obtained by objective techniques from standard inputs derivable from routine FAA and NOAA observations.

The primary focus of attention with the dependent data is on validation of the more stringent case of one-hour observations recognizing, nevertheless, that the standards variously relate to one-hour, 8-hour, 6-9a.m., 24-hour, and longer-term concentrations. In the work with the modified model described later; we extend the time periods to more specifically relate to the individual standards.

The initial sample of data employed in the tests consisted of a ten-day (7 through 16 November 1972) set of observations of CO, NO_2 and suspended particulates at from three to seven stations inside the airport environs (see the Program Plan). Attention was most often focussed on six hours (0100-0200, 0500-0600, 0900-1000, 1300-1400, 1700-1800, and 2100-2200), selected because they defined the average aircraft activity curve (Figure 25), and also gave a broad spectrum of other input. These data were used in various sets and combinations in the comparisons described in the Appendix H.

A second set of data, used for validation of the non-methane hydrocarbons, came from Station 2 for period 6 through 21 December 1972.

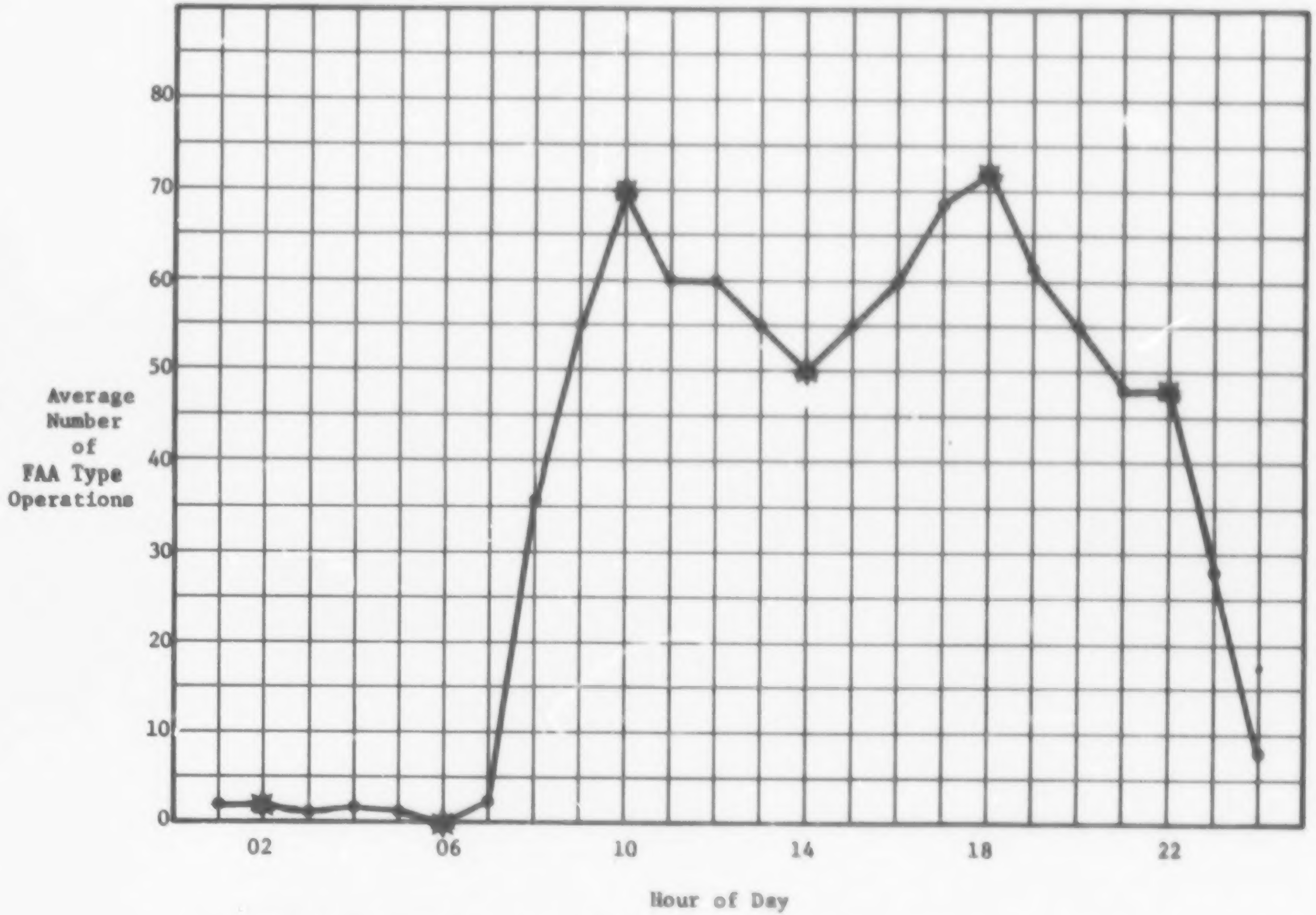

Figure 25. Average Number of FAA Type Operations (Landings plus Takeoffs) through the Day at DCA, Selected because they Define Average Aircraft Activity Curve.

The NREC Model Compared to the Dependent Data Sample

The basic NREC model is described in the preceding section with that title, and the computer program description is given in Appendix E. Special attention is again invited to the portion of the section on the NREC model which describes the way in which it was implemented for this project, and that this implementation involves differences which, while not apparently significant in themselves, generate significant differences in the predicted results. The following discussion of our results with the NREC model should be considered in light of the fact that informal findings from the use of the model by others (Zimmerman, 1972) have reported consistent underprediction by an order of magnitude.

As stated before, the NREC model is driven by the principal inputs of aircraft activity and meteorological parameters. For ease of reference, in the following discussion of results, figures and reproduction of reduced printouts, the model is referred to as simply "NREC."

All comparisons of the dependent data in this section with the NREC model, and in the next section with the GEOMET model, involve use of data from all stations combined. Examination of station-by-station comparisons was reserved for later comparisons of GEOMET with the independent sample, which could be made sufficiently large to permit such analyses.

The principal results for each of the four pollutants are presented in Figures 26 through 29, and Table 12. The figures and table show the general tendency of the bulk of the NREC predictions to be significantly below the observations, although for NO_2 and particulates the highest range of the predictions is higher than the corresponding range of the observations (above the 90-95th percentiles). The predicted medians, means and 98th precentiles are shown in Table 13 as fractions of the corresponding observed parameters.

The general underprediction is evident in these tables, except for NO_2 and particulates, where the crossing of the distributions brings the means to essential equality $\left(\text{mean}\left(\frac{\text{obs}}{\text{pred}}\right) \simeq 1\right)$. Nontheless, except for the NMHC model values, the degree of underpredictiction with this implementation

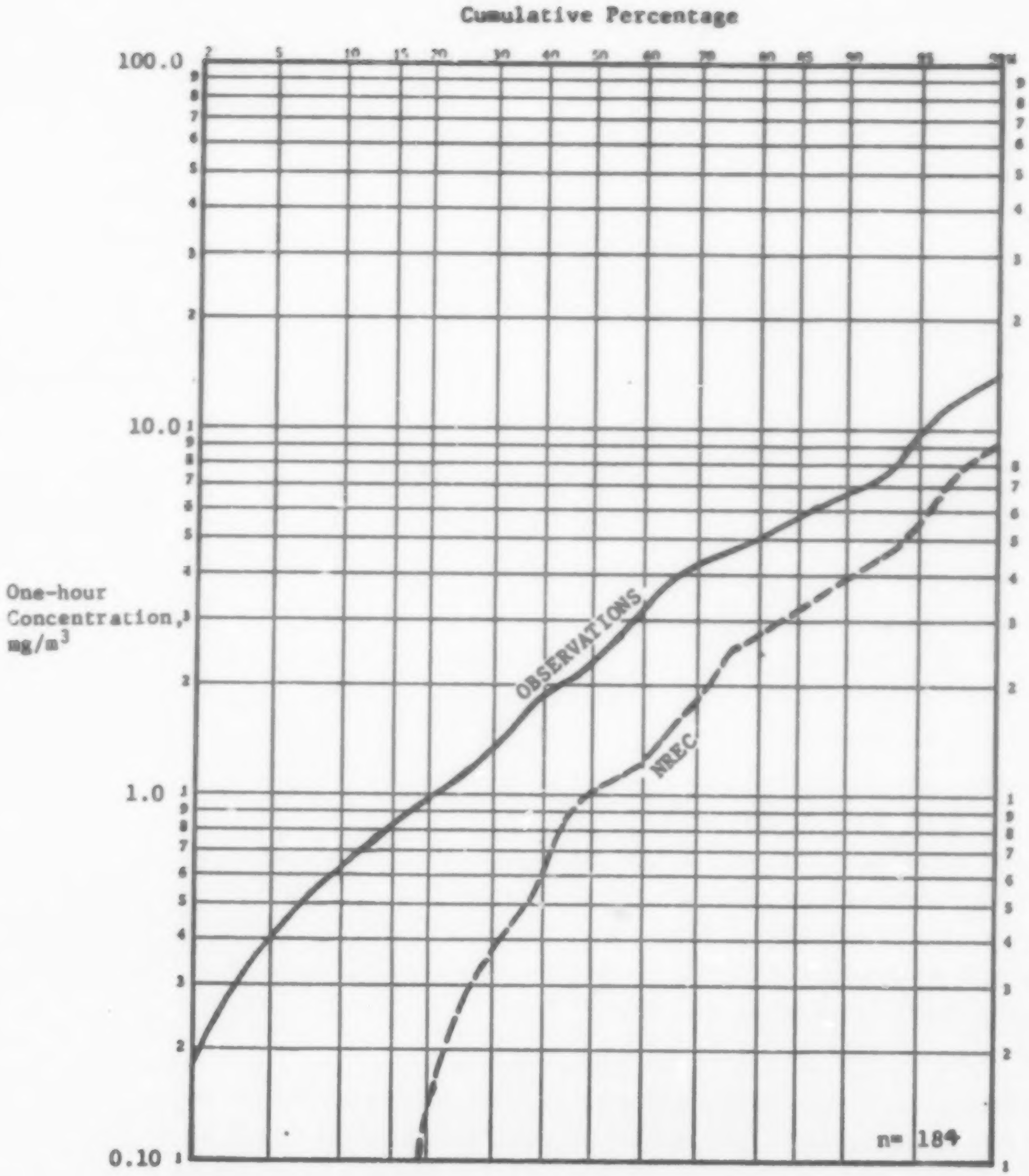

Figure 26. Frequency Distributions of Observed and Predicted (NREC) Concentrations of CO; Six Selected Hours Per Day, 7-16 November 1972, Washington National Airport Stations 4, 5 and 7 (plus 10 hours from station 1).

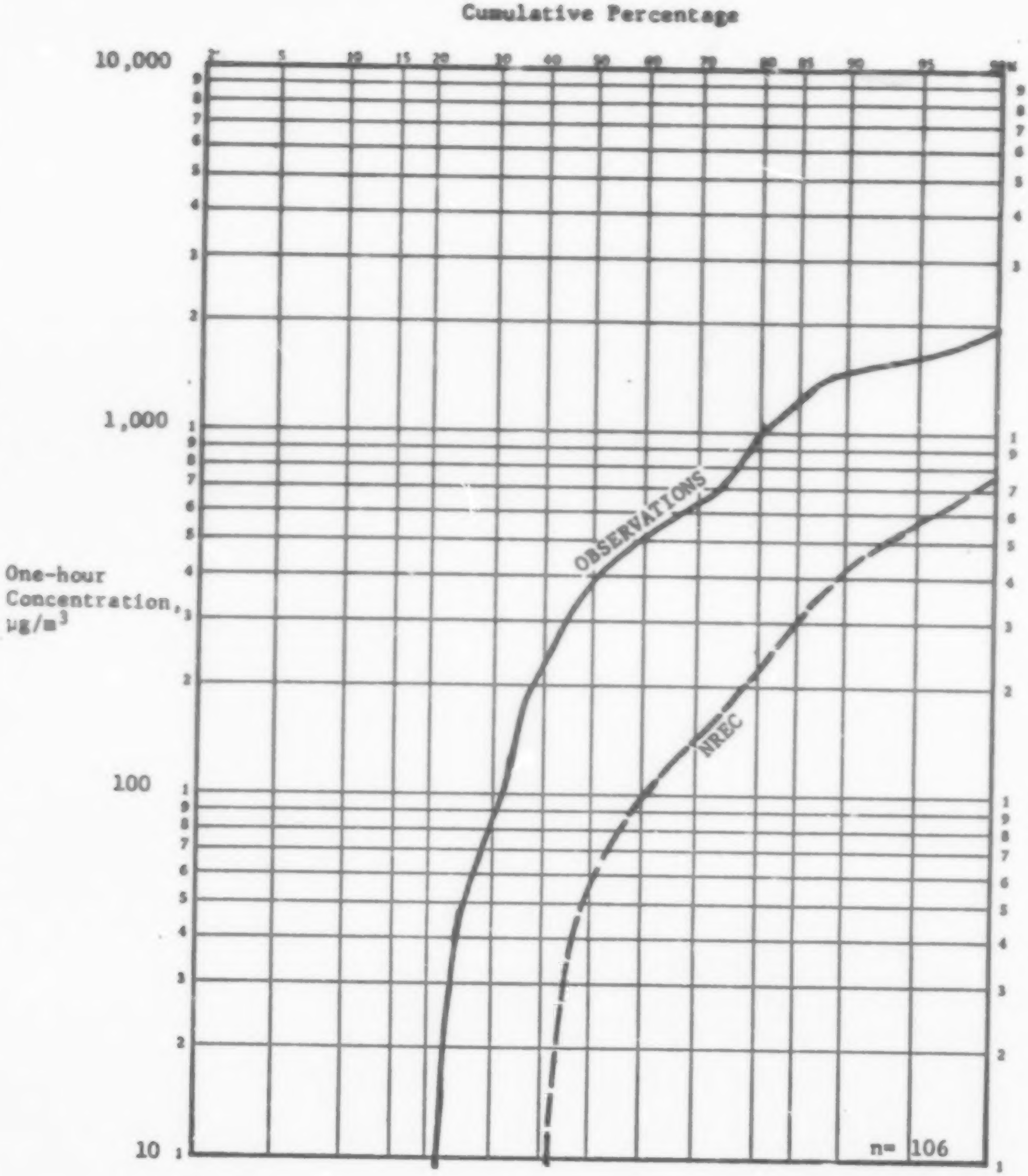

Figure 27. Frequency Distributions of Observed and Predicted (NREC) Concentrations of Non-Methane Hydrocarbons; 6 December 1972 (24 Hours), and Six Selected Hours Per Day, 7-21 December 1972, Washington National Airport Station 2.

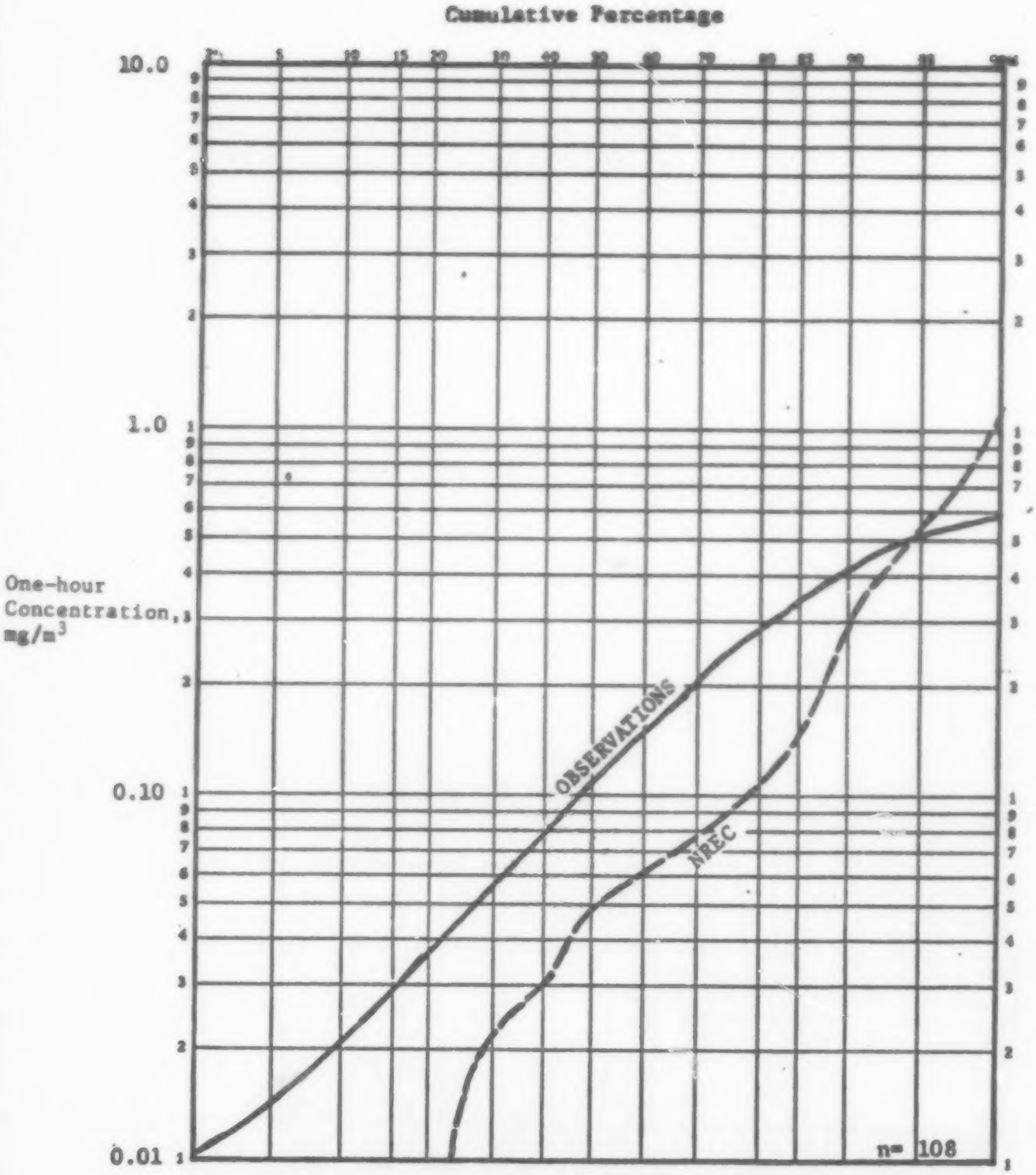

Figure 28. Frequency Distributions of Observed and Predicted (NREC) Concentrations of NO_2; Six Selected Hours Per Day, 7-16 November 1972, Washington National Airport Stations 2, 3 and 6.

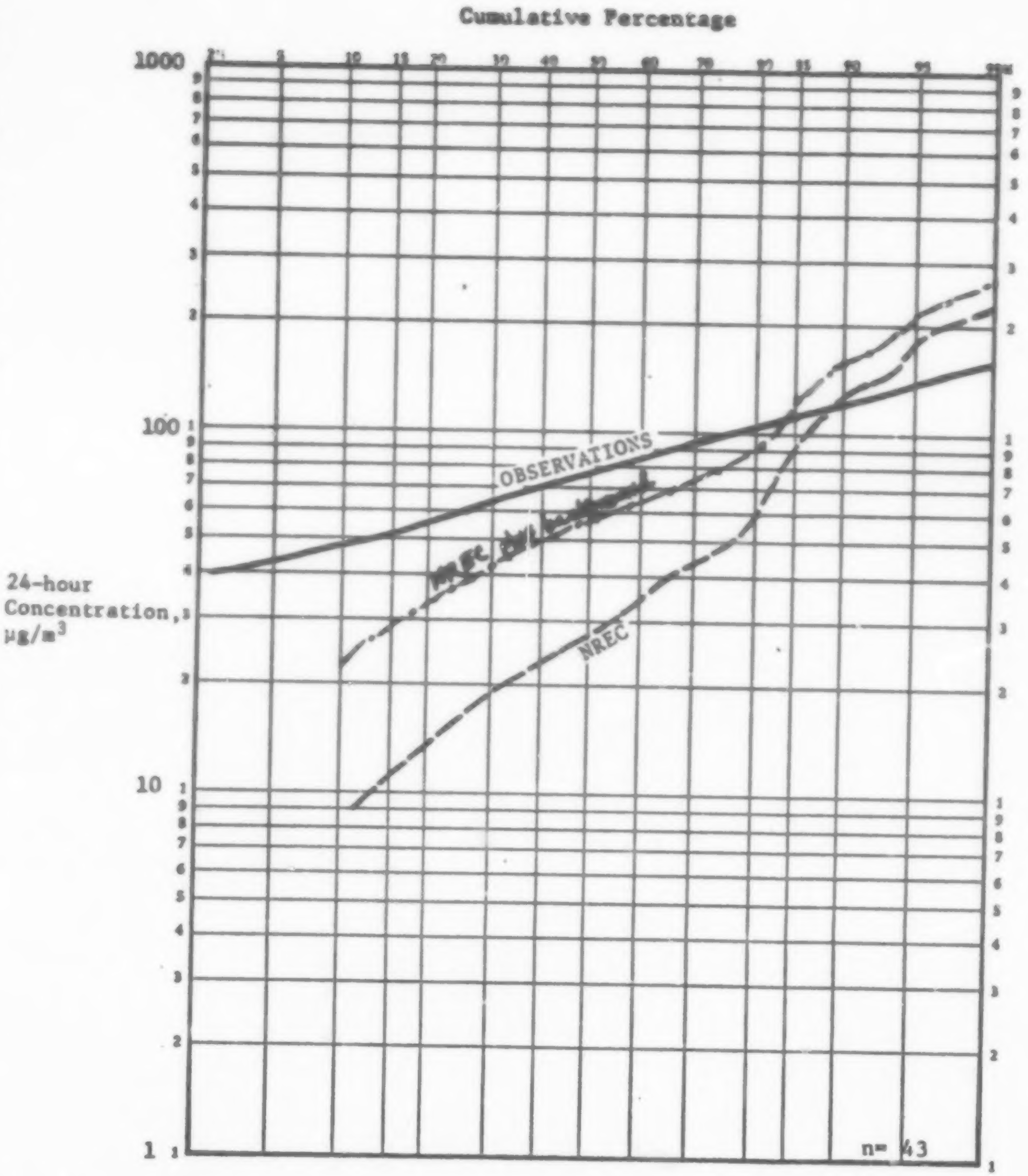

Figure 29. Frequency Distributions of Observed and Predicted (NREC, Average of Six Selected Hours Per Day) 24-Hour Concentrations of Suspended Particulates, 7-16 November 1972, Washington National Airport Stations 1 through 7.

Table 12. The NREC Model and the Dependent Data Sample: Statistics of the Predictions and Observations for All Stations Combined (see text)

		Number of Cases	Distributional Statistics								
			10%	25%	50%	75%	90%	98%	Mean	r*	Sign Test**
CO 1-hr, mg/m^3	Pred.	184	0.0	0.29	1.07	2.45	4.00	8.94	1.94	0.026	44/184
	Obs.		0.57	1.14	2.90	4.60	6.90	15.4	3.71		
NMHC 1-hr, μg/m^3	Pred.	106	0.0	0.0	51	139	401	715	143	-0.034	35/106
	Obs.		0.0	27	353	670	1468	2066	527		
NO_2 1-hr, μg/m^3	Pred.	108	0.0	0.01	0.05	0.09	0.29	2.14	0.18	0.134	31/108
	Obs.		0.03	0.05	0.12	0.26	0.43	0.60	0.18		
Particulates (inc. background) 24-hr, μg/m^3	Pred.	43	23.0	38.0	56.5	76.6	157	258	81.5	-0.071	8/43
	Obs.		48.0	60.0	75.8	93.0	125	157	82.8		

* r = Coefficient of correlation.

** Sign test = the fraction (of the total n) of positive or negative values (whichever is smaller) of the differences between observation and prediction.

of NREC is nowhere near as extreme as has been reported unofficially (Zimmerman, 1972) by other users of NREC following the procedures of the NREC report (factors of the order of ten). The various statistics, interpretable according to Appendix G, support the general findings of a tendency to underpredict, both in means and distributions, and, in the case of statistics which test the hour-by-hour matching of paired values, show poor results, reflecting the large degree of scatter which is characteristic of comparisons of observations with predictions from steady-state type models such as this. These four cases are given as examples in Appendix G.

Table 13. THE NREC MODEL AND THE DEPENDENT DATA SAMPLE: STATISTICS OF THE PREDICTIONS AS FRACTIONS OF THE CORRESPONDING STATISTICS OF THE OBSERVATIONS

Pollutant / Statistic Comparison	CO	NMHC	NO_2	Particulates (incl. background)
Median $\frac{\text{Pred}}{\text{obs.}}$	0.36	0.14	0.42	0.75
Mean $\frac{\text{Pred}}{\text{obs.}}$	0.52	0.27	0.99	0.98
98 Percentile $\frac{\text{Pred}}{\text{obs.}}$	0.58	0.35	3.57	1.64

The Modified (GEOMET) Model Compared to the Dependent Data Sample

This section parallels the previous one on the NREC model, in that the same tests were run with the same dependent data sample. The model involved the modifications described in the Section titled The Modified Model, and were implemented as described in the section on implementing the NREC model. And again, the introductory comments in the Section titled Model Constraints should be considered in assimilating the following results.

The principal results for each of the four pollutants are presented in Figures 30 through 33, and Table 14. The predicted CO distribution is quite close to the observed distribution now, except above the 90th percentile, where the prediction tends higher. The particulate distribution has moved closer than for NREC; and the NMHC and NO_2 predicted distributions are both consistently higher than the observations. The predicted medians, means and 98th percentile values are shown in Table 15 as fractions of the corresponding observed parameters.

The correspondence of the medians and means for CO and particulates is quite good, although both show the same tendency to have somewhat higher maximum values for the predictions. As indicated in the earlier discussion on Model Constraints, in a non-reactive model which is behaving properly, one would inferentially expect overprediction in the case of NMHC and NO_2, although the true situation for these pollutants is undoubtedly more complex than this. In any event, Table 15 shows varying, sometimes extreme, degrees of overprediction for NMHC and NO_2.

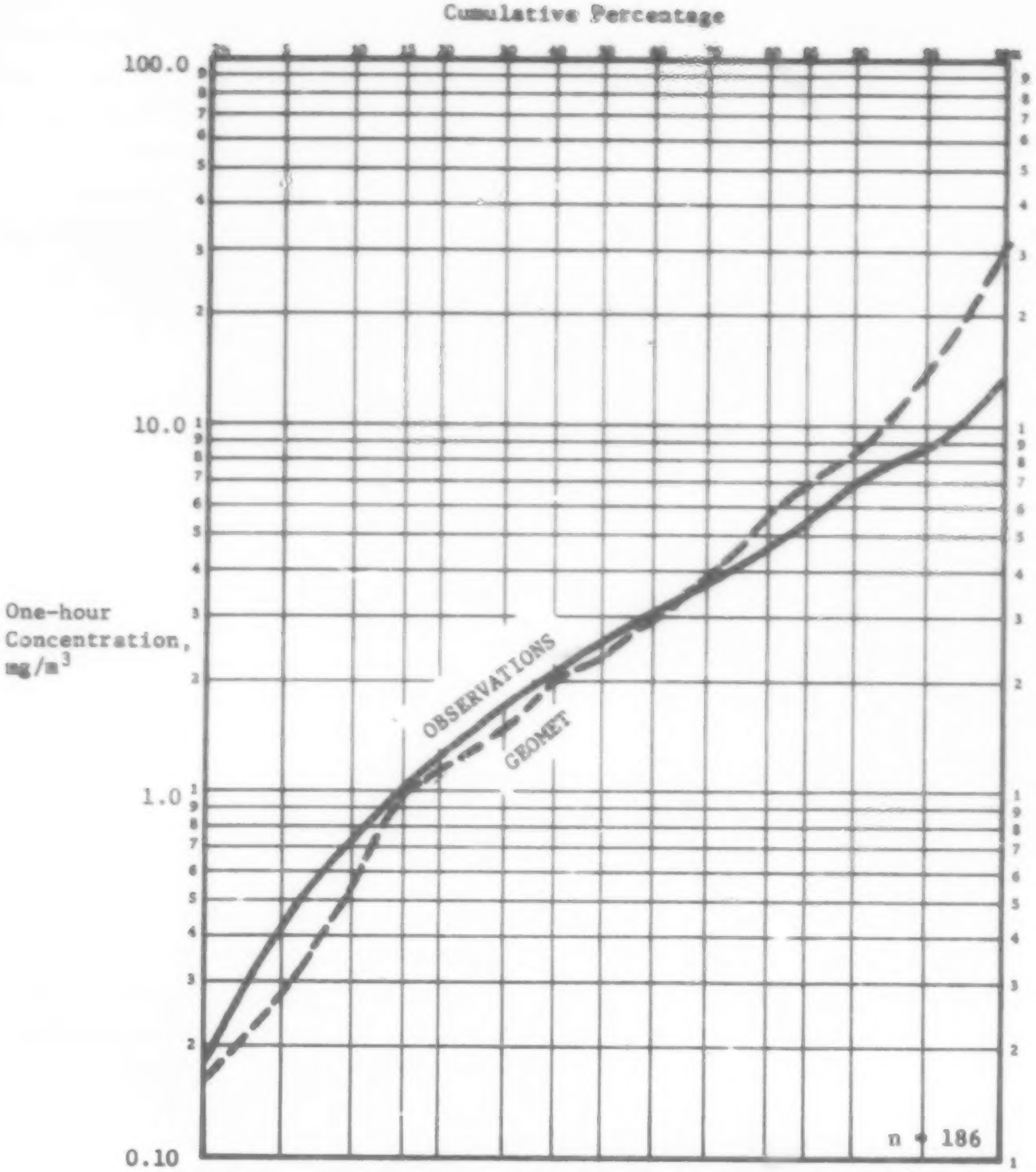

Figure 30. Frequency Distributions of Observed and Predicted (GEOMET) Concentrations of CO; Six Selected Hours Per Day, 7-16 November 1972, Washington National Airport Stations 4, 5 and 7 (plus 10 hours from Station 1).

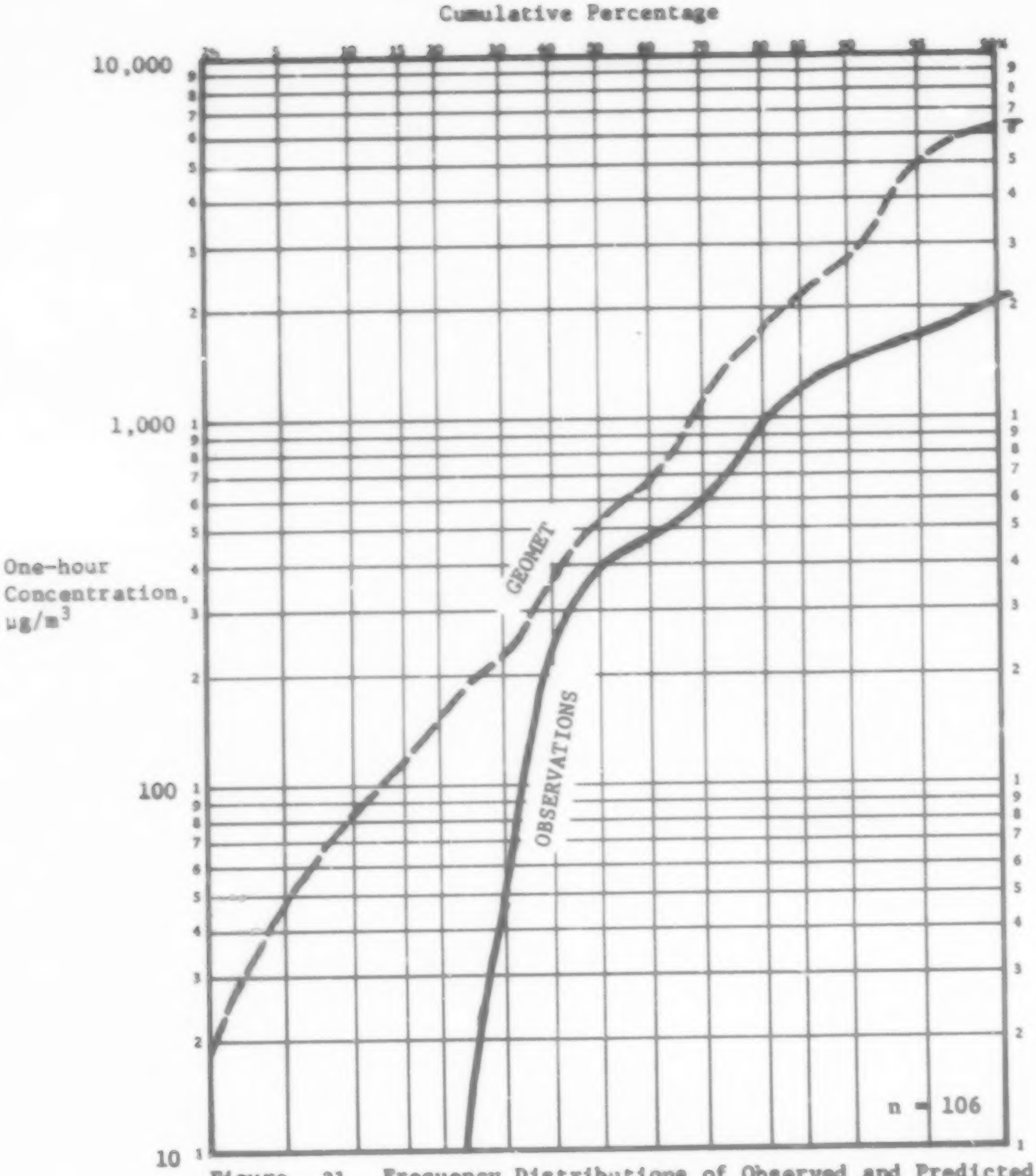

Figure 31. Frequency Distributions of Observed and Predicted (GEOMET) Concentrations of Non-Methane Hydrocarbons; 6 December 1972 (24-hours), and Six Selected Hours Per Day, 7-21 December 1972, Washington National Airport Station 2.

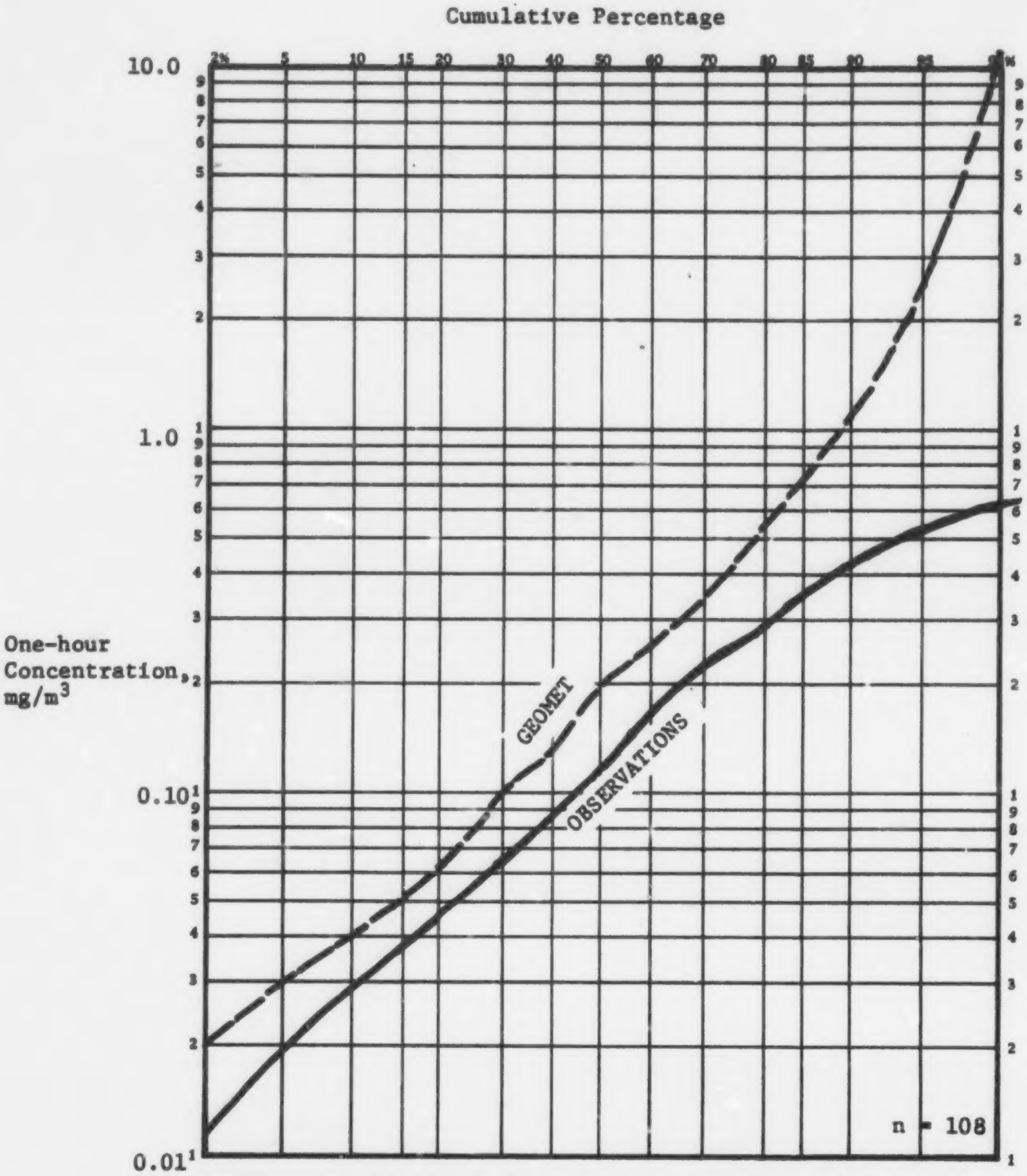

Figure 32. Frequency Distributions of Observed and Predicted (GEOMET) Concentrations of NO_2; Six Selected Hours Per Day, 7-16 November 1972, Washington National Airport Stations 2, 3 and 6.

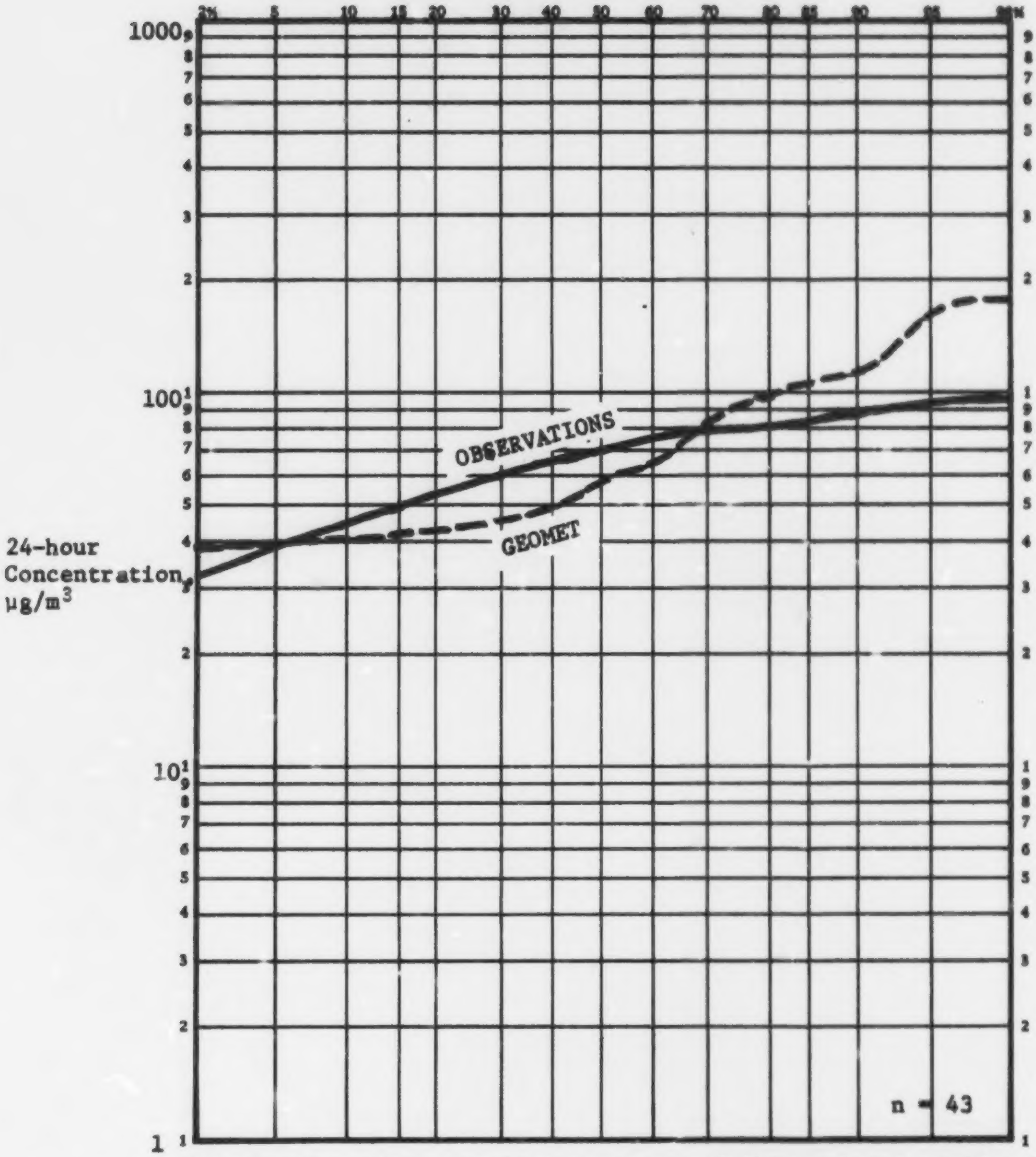

Figure 33. Frequency Distributions of Observed and Predicted (GEOMET, Average of Six Selected Hours Per Day) 24-Hour Concentrations of Suspended Particulates, 7-16 November 1972, Washington National Airport Stations 1 through 7.

Table 14. The GEOMET Model and the Dependent Data Sample: Statistics of the Predictions and Observations for All Stations Combined (see text)

		Number of Cases	Distributional Statistics								
			10%	25%	50%	75%	90%	98%	Mean	r*	Sign Test**
CO 1-hr, mg/m^3	Pred. Obs.	180	0.53 0.57	1.34 1.14	2.37 2.30	4.27 4.00	8.52 6.80	32.2 13.7	4.36 3.26	-0.068	84/180
NMHC 1-hr, μg/m^3	Pred. Obs.	106	85 0.0	200 27	530 399	1461 735	2753 1470	6116 2070	1145 527	0.101	37/106
NO_2 1-hr, μg/m^3	Pred. Obs.	106	0.04 0.03	0.08 0.05	0.20 0.13	0.38 0.27	1.15 0.43	11.5 0.61	0.66 0.18	0.25	35/106
Particulates (inc. background) 24-hr, μg/m^3	Pred. Obs.	21	40.4 44.5	44.4 58.0	59.4 69.0	88.1 80.4	117.1 86.6	180.3 95.1	68.8 66.7	0.15	9/21

* r = Coefficient of correlation.

** Sign Test = the fraction (of the total n) of positive or negative values (whichever is smaller of the differences between observation and prediction.

Table 15. THE GEOMET MODEL AND THE DEPENDENT DATA SAMPLE: STATISTICS OF THE PREDICTIONS AS FRACTIONS OF THE CORRESPONDING STATISTICS OF THE OBSERVATIONS

Pollutant / Statistic Comparison	CO	NMHC	NO_2	Particulates (incl. background)
Median $\frac{\text{Pred}}{\text{obs.}}$	1.03	1.33	1.54	0.86
Mean $\frac{\text{Pred}}{\text{obs.}}$	1.34	2.17	3.67	1.03
98th Percentile $\frac{\text{Pred}}{\text{obs.}}$	2.35	2.95	18.97	1.90

The various statistics for these data may be summarized as follows: the "t" tests show good comparisons of the means for CO and particulates and the "pairs" tests are also good for these two. The other statistics still show the general lack of correlation of hour-by-hour pairs as before, although some modest degree of correlation appears in some cases. An increased correlation for NO_2, while modest, is interesting, since it shows that, even though there is a strong tendency to overpredict, the observations and predictions tend to correlate in relative, even though not absolute, magnitude. This is an incidental indication that might warrant future investigation of the use of non-reactive models for study of reactive pollutants.

The principal results, however, are reflected in the significant improvement over NREC in predictive capability for the non-reactive pollutants, coupled with a tendency to predict somewhat higher maximum values than the observations. This sets the stage for proceeding on to the independent data sample and the final validation tests and analysis, described in the succeeding sections.

The Independent Data Sample

In selecting the large independent data sample for final validation of the GEOMET model, several objectives were sought: a sample for each pollutant was required which was large enough to give an adequate representation of the model's validity, including coverage of the entire six months of data gathering, and yet not so large as to require a prohibitive amount of computer running to generate the predictions. For comparison with standards, predictions were required for an adequate number of values for each station for: 1-hour and 8-hour values of CO, 3-hour (6-9a.m.) values of non-methane hydrocarbons, 1-hour values of NO_2 (to generate the mean), and 24-hour values of particulates. Each 3-hour, 8-hour and 24-hour prediction must be generated by generating, respectively, three, eight and twenty-four single hour predictions, and averaging them.

For CO, NO_2 and particulates, the first step was to select a reasonable sample of days, as shown in Table 16.

For NMHC, since the monitoring equipment was not completely in place until after most of the sampling had gotten under way, and only one period (6-9am) was of validation interest for each day selected, the procedure was to select most of the days on which at least two of the three NMHC instruments were operating.

In all, the selection process generated 5,401 single-hour predictions, the total numbers of predictions given in the first column of Table 17. Also shown are the numbers of averages calculated from these where appropriate, and the smaller number of predictions, subsumed within the totals, which could actually be used in validation analysis, there being valid observations to match (the scheme chosen for selection of validation periods will occasionally hit upon a period for which the observation is missing); in validation analysis this station-hour is dropped from the sample.

The observations listed in the right-hand portion of Table 17 have been used in a variety of validation analyses of the GEOMET model, as described in the next section.

The Modified (GEOMET) Model Compared to the Independent Data Sample

The GEOMET model was employed in these validations exactly as described in the previous section on validating it against the dependent sample. The results are presented first as they were in that section, and subsequently elaborated and discussed in greater detail. Worthy of note is that, while the smaller dependent data sample inputs and observations were prepared by hand, in the independent sample cases all extraction of input data was done automatically from the disk records; the validation observations were obtained similarly.

The principal results for each of the four pollutants are presented in Figures 34 through 40, and Tables 18 and 19. These represent all stations combined,* as before, for the NREC and GEOMET models with the dependent sample. The more important station-by-station validations are presented later in this section.

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*Footnote: The figures and tables of the "combined station" data are given to permit comparison with the dependent data analyses of the previous section, and to facilitate diagnosis of the results.

Table 16. DAYS SELECTED FOR INDEPENDENT DATA SAMPLE

Day Number	Date	Day of Week	Julian Date (for computer use)
1	21 November 72	Tuesday	72326
2	1 December 72	Friday	72336
3	12 December 72	Tuesday	72347
4	21 December 72	Thursday	72356
5	27 December 72	Wednesday	72362
6	4 January 73	Thursday	73004
7	14 January 73	Sunday	73014
8	26 January 73	Friday	73026
9	3 February 73	Saturday	73034
10	14 February 73	Wednesday	73045
11	26 February 73	Monday	73057
12	4 March 73	Sunday	73063
13	15 March 73	Thursday	73074
14	21 March 73	Wednesday	73080
15	23 March 73	Friday	73082
16	24 March 73	Saturday	73083
17	27 March 73	Tuesday	73086
18	2 April 73	Monday	73092
19	5 April 73	Thursday	73095
20	13 April 73	Friday	73103
21	20 April 73	Friday	73110
22	23 April 73	Monday	73113

Table 17. NUMBERS OF: SINGLE-HOUR PREDICTIONS GENERATED FOR EACH POLLUTANT, LONGER-PERIOD AVERAGES CALCULATED, AND NUMBERS USABLE FOR VALIDATION; FOR THE INDEPENDENT DATA SAMPLE

		TOTALS		USABLE FOR VALIDATION	
Pollutant	Station	Predictions Generated	Averages Calculated	1-Hour	Longer Term (as shown)
		1-hr.	8-hr.		8-hr.
CO	1	176	22	47	6
	2	176	22	66	10
	3	176	22	144	19
	4	176	22	135	18
	5	176	22	145	19
	6	176	22	96	12
	7	176	22	159	21
	8	176	22	86	11
	Totals	1408	176	878	116
			6-9a.m.		6-9a.m.
NMHC	2	231	77	146	77
	3	231	77	201	77
	6	231	77	151	77
	Totals	693	231	498	231
NO_2	2	132		108	
	3	132		106	
	6	132		38	
	Totals	396		252	
			24-hr.		24-hr.
Particulates	1	264	11		4
	2	528	22		22
	3	528	22		21
	4	264	11		10
	5	264	11		11
	6	528	22		13
	7	264	11		11
	8	264	11		6
	Totals	2904	121		103
	Total	5401			

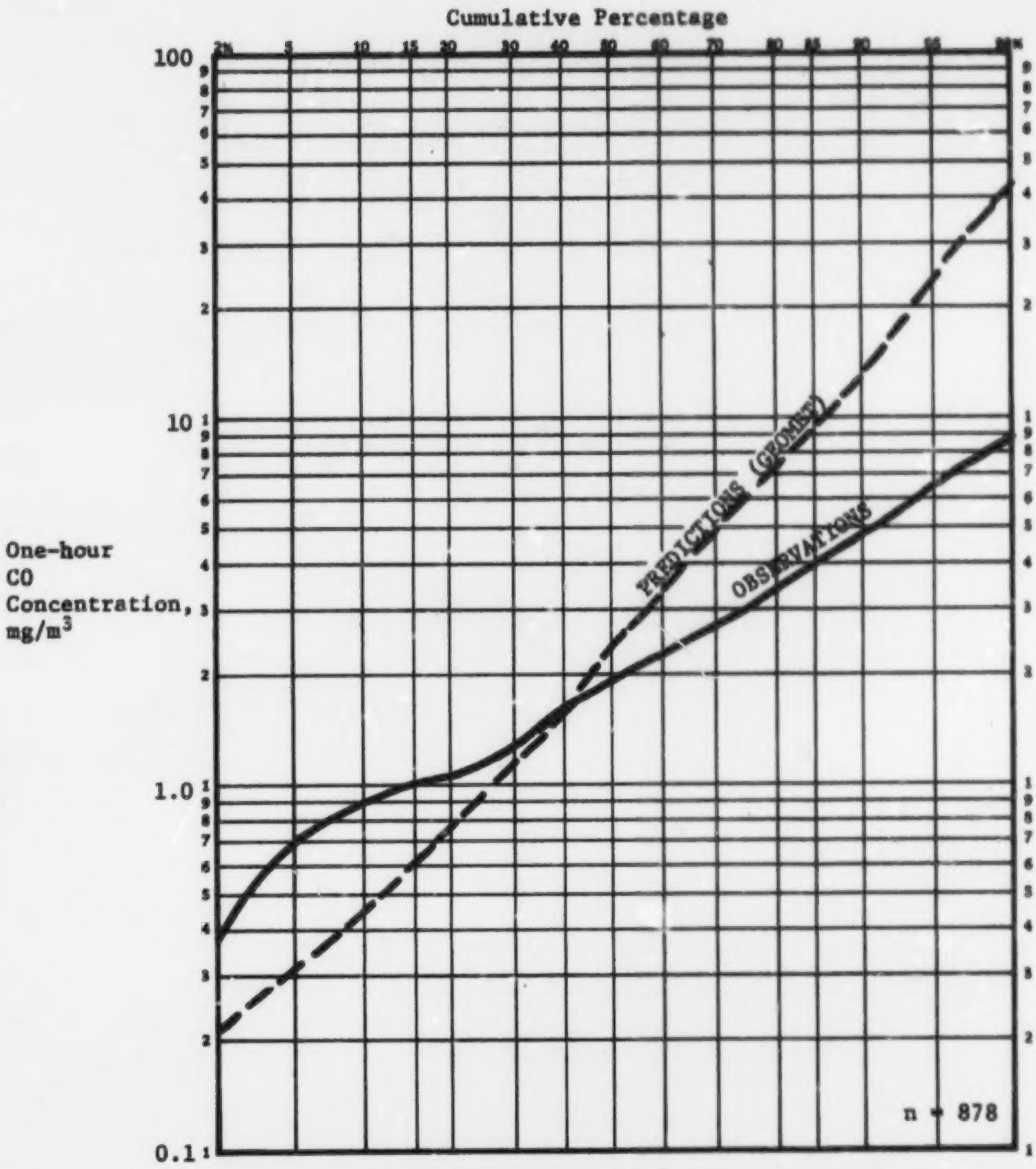

Figure 34. Frequency Distribution of Observed and Predicted Concentration of CO; Independent Data Sample, All Stations.

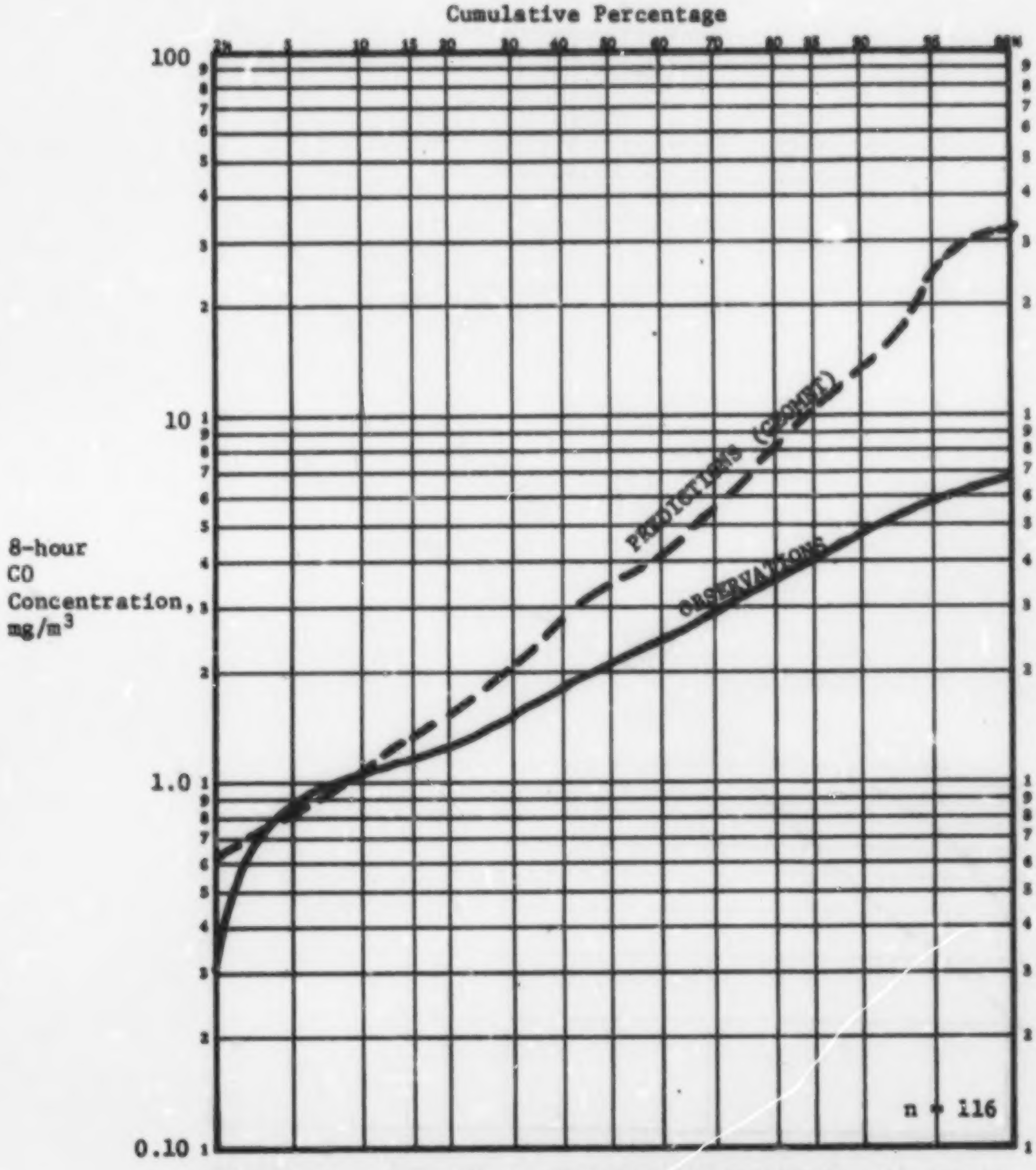

Figure 35. Frequency Distribution of Observed and Predicted Eight-Hour Concentration of CO; Independent Data Sample, All Stations.

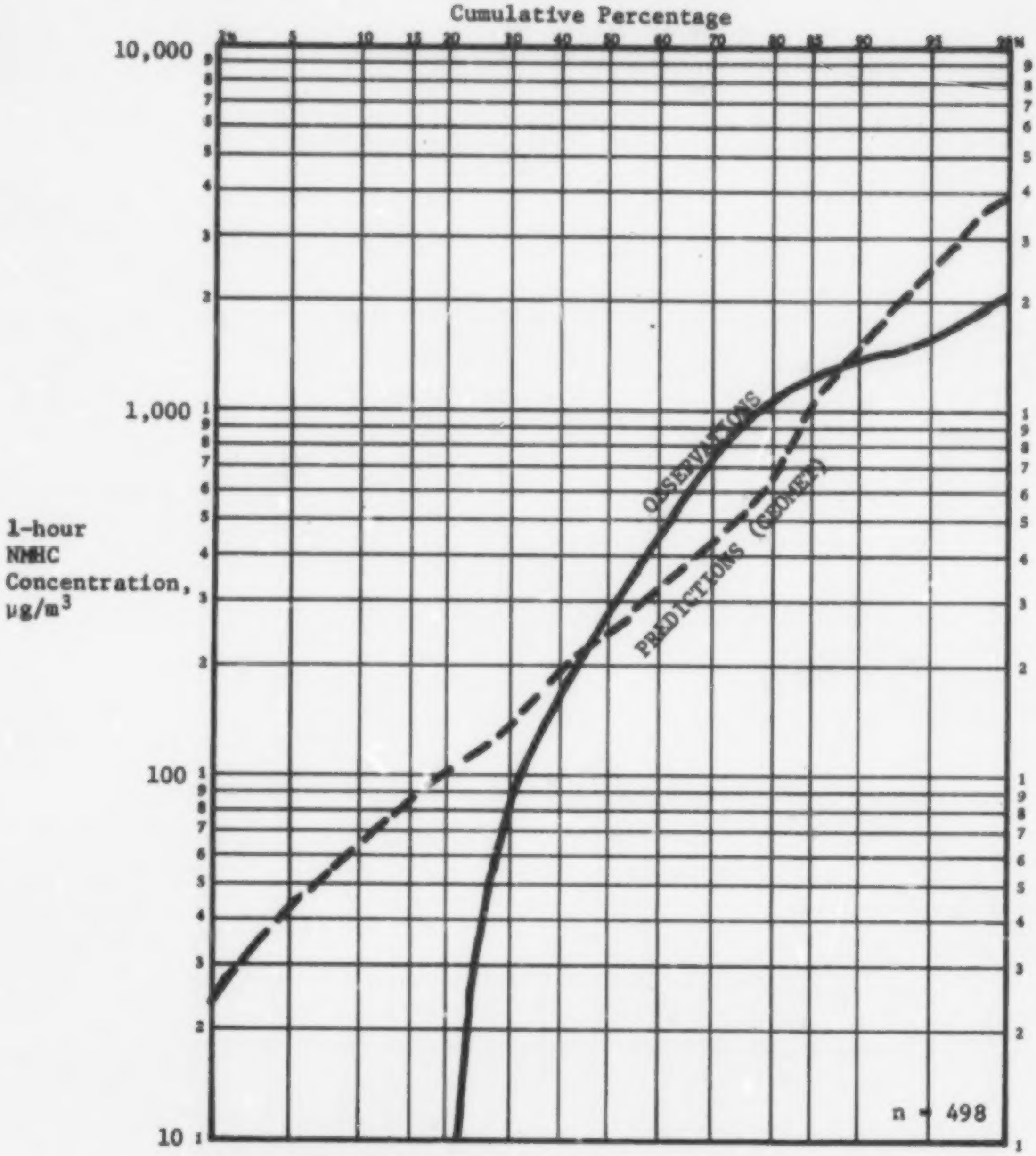

Figure 36. Frequency Distributions of Observed and Predicted (GEOMET) Concentrations of Non-Methane Hydrocarbons, Independent Data Sample; Stations 2, 3 and 6.

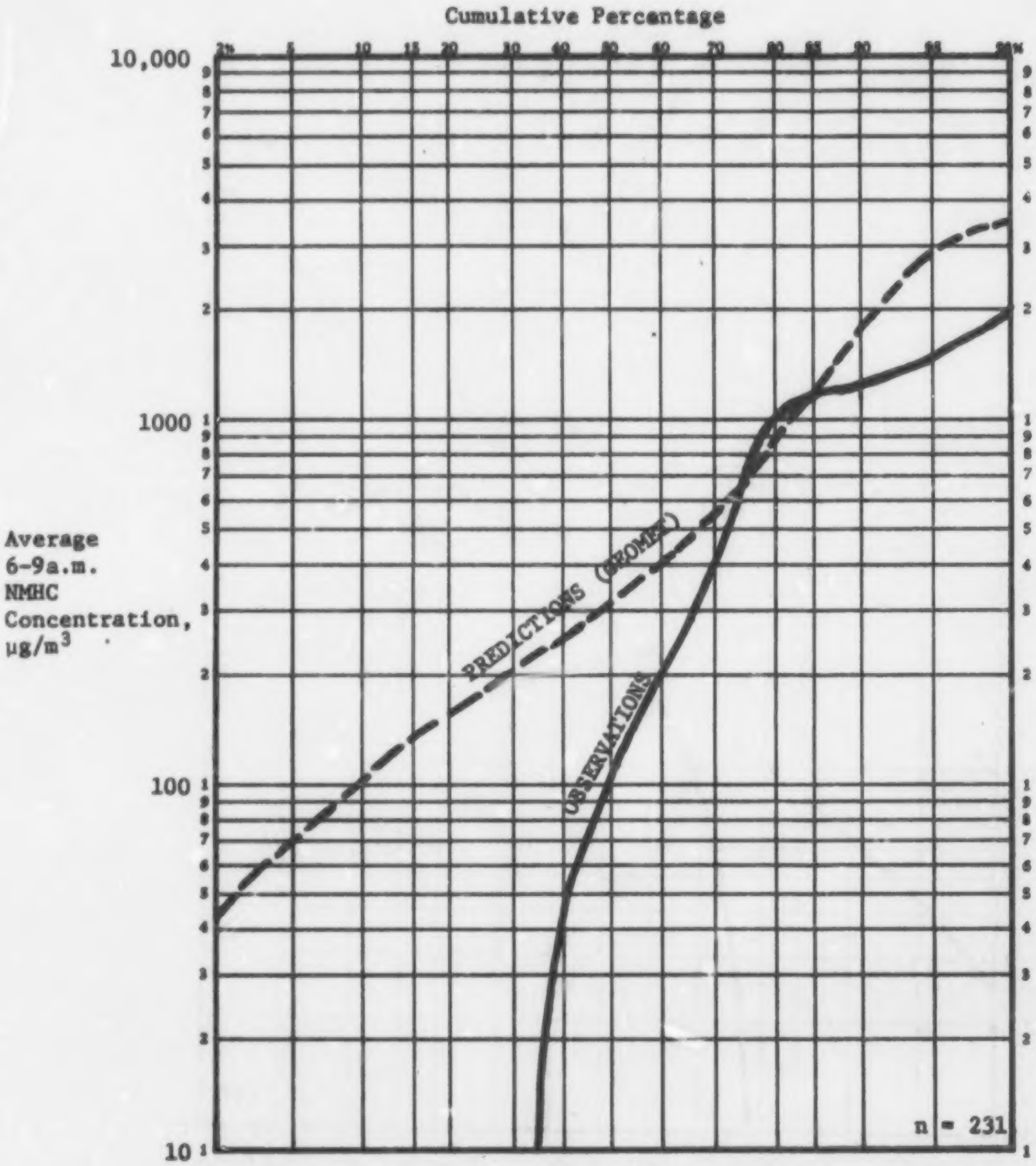

Figure 37. Frequency Distributions of Observed and Predicted (GEOMET) Concentrations (6-9a.m. only) of Non-Methane Hydrocarbon; Independent Data Sample; Stations 2, 3 and 6.

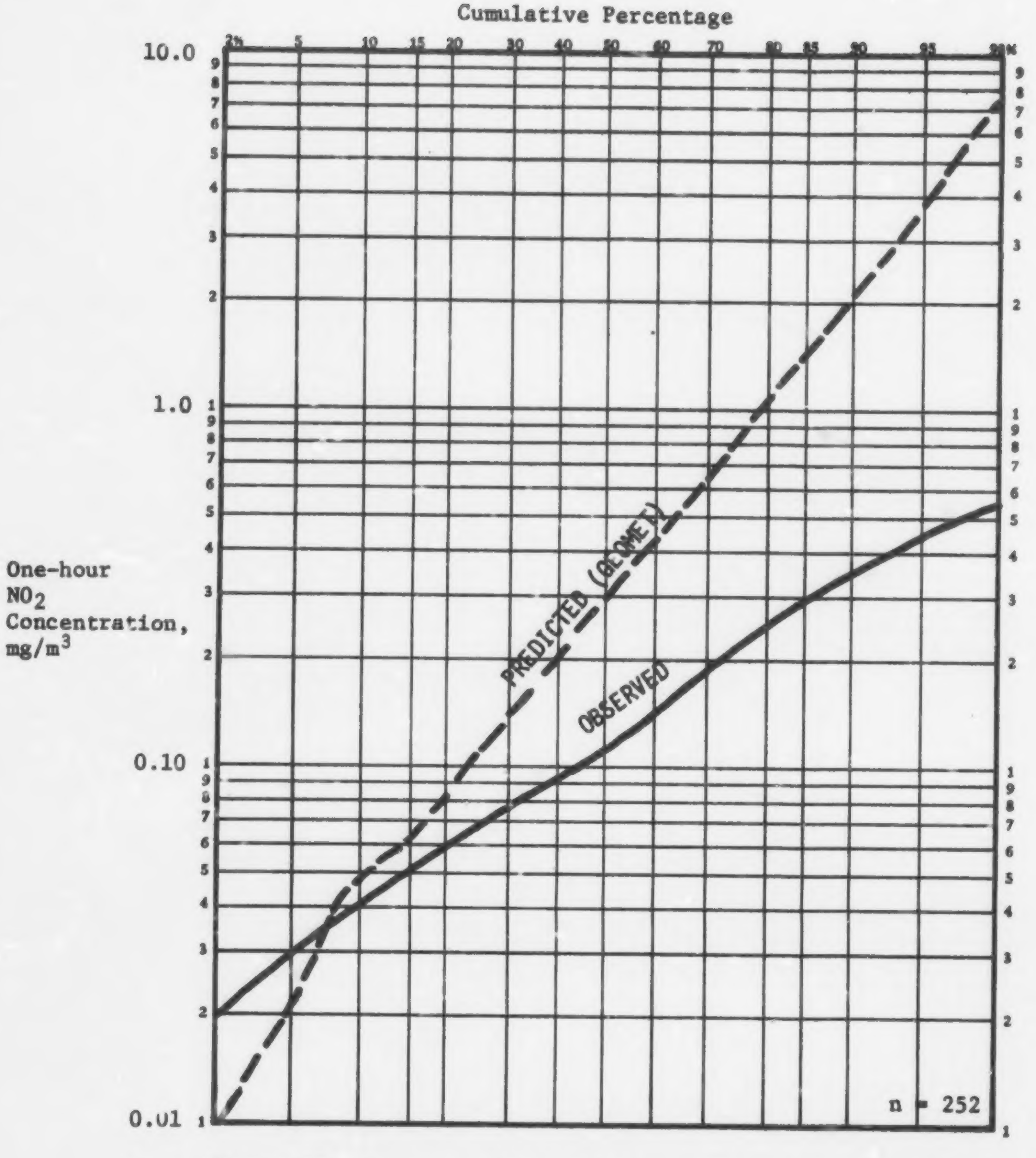

Figure 38. Frequency Distribution of Observed and Predicted (GEOMET) Concentration of NO_2; Independent Data Sample; Stations 2, 3 and 6.

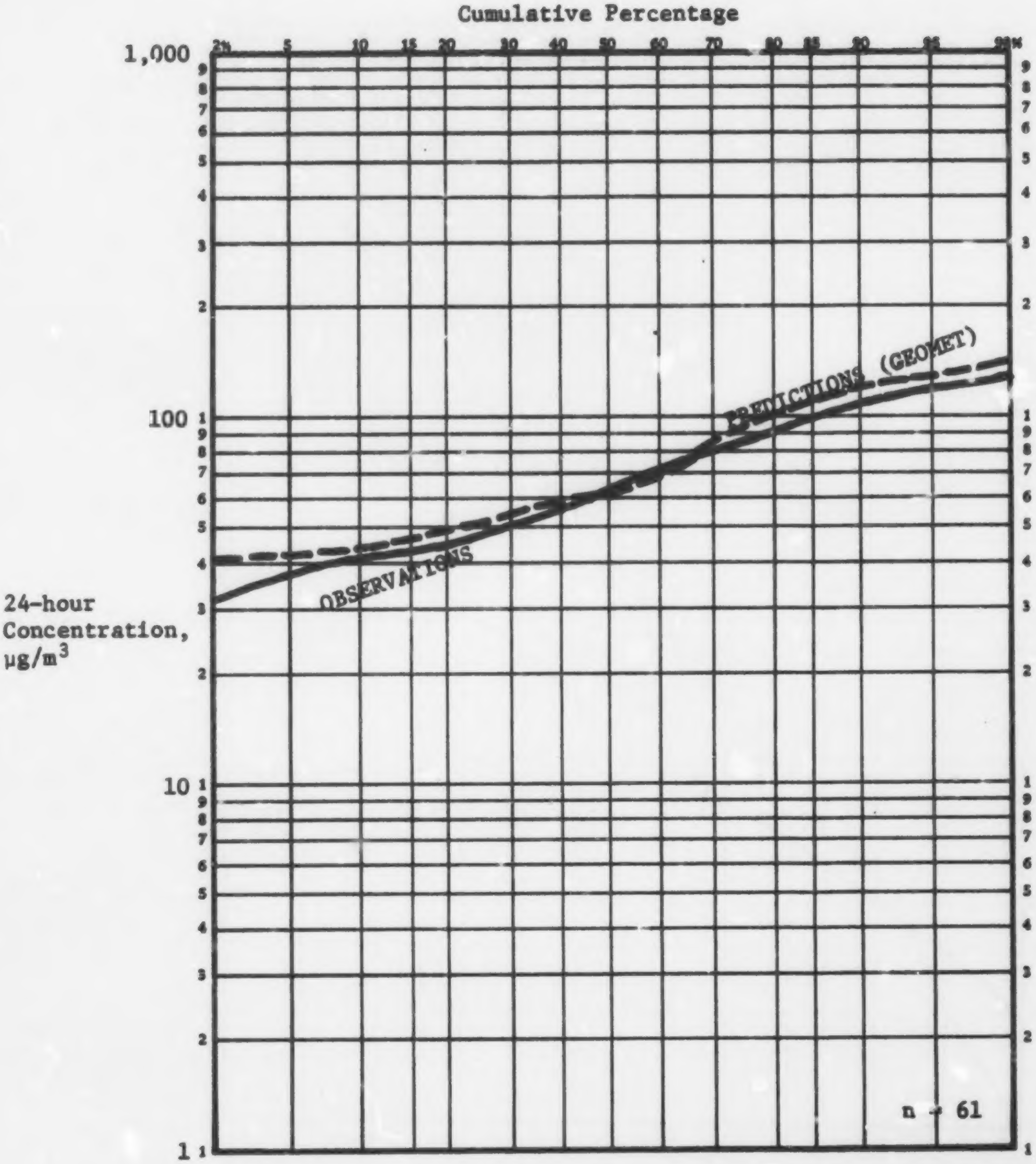

Figure 39. Frequency Distribution of Observed and Predicted (GEOMET) 24-Hour Concentrations of Particulates; Stations 2,3 and 6. Independent Data Sample.

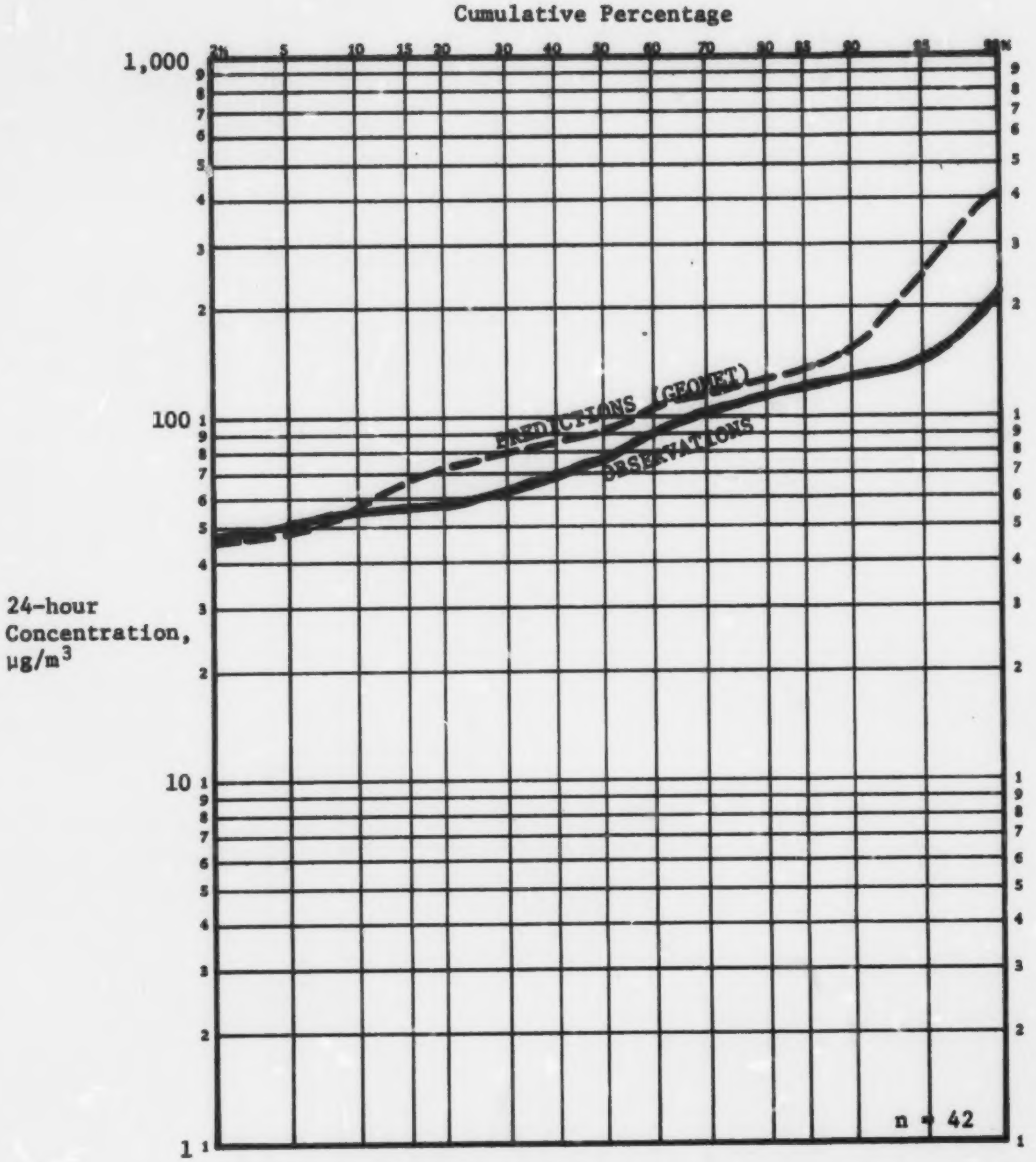

Figure 40. Frequency Distribution of Observed and Predicted (GEOMET) 24-Hour Concentrations of Particulates; Stations 1, 4, 5, 7 and 8.
Independent Data Sample.

Table 18. The GEOMET Model and the Independent Data Sample, Compared Using Data from All Stations Combined: Statistics of the Predictions and Observations (for comparison with Table 19)

		Number of Cases	Distributional Statistics								
			10%	25%	50%	75%	90%	98%	Mean	r*	Sign Test**
CO 1-hr, mg/m^3	Pred. Obs.	878	0.46 0.90	1.00 1.18	2.52 2.00	6.09 3.20	14.8 5.10	46.9 8.5	6.06 2.53	0.193	373/878
NMHC 1-hr, μg/m^3	Pred. Obs.	498	64 0	122 34	256 280	525 1065	1602 1504	3930 2032	586 564	-0.122	248/498
NO_2 1-hr, μg/m^3	Pred. Obs.	252	0.05 0.05	0.11 0.07	0.28 0.12	0.82 0.22	2.09 0.36	7.56 0.52	0.82 0.16	0.084	75/252
Particulates (incl. background) 24-hr, μg/m^3 - Stations 2,3,6	Pred. Obs.	61	44.3 40.4	52.8 47.5	64.1 62.3	89.5 85.6	132.2 114.5	156.5 138.0	74.9 68.5	0.233	26/61
Particulates (inc. background) 24-hr, μg/m^3 - Stations 1,4,5, 7,8	Pred. Obs.	42	58.8 55.8	75.8 61.3	90.5 79.5	140.8 112.6	168.3 136.3	414.7 222.9	111.6 88.3	0.154	12/42

* r = Coefficient of correlation.

** Sign Test = the fraction (of the total n) of positive or negative values (whichever is smaller) of the differences between observation and prediction.

Table 19. THE GEOMET MODEL AND THE INDEPENDENT DATA SAMPLE: STATISTICS OF THE PREDICTIONS AS FRACTIONS OF THE CORRESPONDING STATISTICS OF THE OBSERVATIONS

Pollutants	CO		NMHC		NO_2	Particulates (24-hour)	
Statistic Comparison	1-hour	8-hour	1-hour	6-9 a.m.	1-hour	Stations 2, 3, & 6	Stations 1, 4, 5, 7 & 8
Median (Pred./Obs.)	1.26	1.75	0.91	2.53	2.33	1.03	1.14
Mean (Pred./Obs.)	2.40	2.44	1.04	1.65	5.13	1.09	1.26
98th Percentile (Pred./Obs.)	5.5	4.86	1.93	1.85	14.54	1.13	1.86

The following observations on validation are made without comment, at least for the moment. Discussion and analysis follow later in this section. The tendency to overpredict the higher values for CO is stronger in this set of sample runs; the median one-hour values are still quite close, however. The higher values warrant later discussion. Pairs and ranks are not bad, and there is even a modest correlation.

For NMHC, the distribution curves cross twice (at 45 percent and 90 percent) and the resulting statistics show means, medians, and high percentiles which are quite similar. The correlation is poor as before. NO_2 shows quite high predictions at the high percentiles. Particulates are presented in two groups of stations because three of them had twenty-two values each, and the other five had eleven each --- they were divided accordingly, for statistical testing purposes. In both cases the means, medians, and 98th percentiles are close, the "t" tests good, and the pair testing generally not bad.

In the cases of the two critical verification pollutants, first, the particulate results have generally been extremely good, and have even improved in moving from the small dependent to the large independent sample; CO, on the other hand, shows a stronger tendency to overpredict. NO_2 and NMHC continue to show the expected overprediction.

While from a statistical point of view our expectation would be that the comparisons would most likely worsen as we pass from a small, dependent sample, used to improve the model, to a larger independent sample covering a longer period, the degree of increase of overprediction of the higher end of the CO distribution is somewhat unexpected. This is discussed further, after the discussion of comparisons for the national air quality standards which follows.

As regards the CO one-hour maximum standard of 40 mg/m^3, and the light hour standard of 10 mg/m^3, the following statements apply. An observed eight-hour maximum of 6.8 means there is no case in 116 which exceeds the standard of ten.* For the predictions, the standard value of ten is crossed at the 85 percentile, which corresponds to some 17 values out of 116 above the eight-hour standard, obviously an excess. The one-hour observed maximum is 16 mg/m^3 which does not exceed the 40 mg/m^3 standard. The prediction exceeds at the 97.5th percentile, equivalent to exceeding the standard 23 out of 878 times, again excessive.

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*Footnote: We ignore, for these and subsequent comparisons, the legal definition that the standard may be exceeded once.

The six to nine a.m. NMHC maximum standard is 160 mg/m^3. This is exceeded in the observations at the 53rd percentile or 109 out of 231 cases. The predicted distribution exceeds at the 20th percentile, which means 185 out of 231 cases. This is greater than the observed exceedance, but both observations and predictions reflect a very large number of exceedances; in that context, the model is reflecting the gross aspects of the observed behavior.

For NO_2, the long-term mean standard is an annual value of 100 µg/m^3, or 0.1 mg/m^3 while our period is for six months, we will compare its mean with the annual value, as a first approximation. The observed mean is 0.161, which exceeds the standard by a factor of 1.61, or 61 percent. The predicted is 0.818, an exceedance of a factor of 8.18, or 718 percent. Thus both show an exceedance, but the prediction is much greater.

Finally, the particulate standards are for an annual geometric mean of 75 µg/m^3, and a 24-hour maximum of 260 µg/m^3. For Stations 2, 3 and 6, at 62 and 64 µg/m^3 respectively, neither predicted nor observed geometric means over six months reach the standard, and at 157 and 138, neither reach the maximum standard. In each case the predictions and observations are very close. This is quite satisfactory performance. For Stations 1, 4, 5, 7, and 8, done separately because of having fewer comparison pairs, the observed and predicted geometric means of 79.5 and 90.5 both exceed the standard, the first by six percent and the second by 21 percent. The maximum observation of 222.9 does not exceed the standard, while the maximum predicted value of 414.7 does, by 60 percent. The standard value occurs at the 95th percentile on the predicted distribution, signifying that degree of overprediction at the high-end of the curve for these stations. This is not as good as the other group, but we will see, a little further on, that this is entirely due to one station, Number 7.

We thus see that in the cases of the two significant pollutants, the particulate verification was generally good in tests against the dependent sample, and tended to improve in tests against the independent sample. The CO performance, which tended to worsen against the independent sample, is discussed subsequently.

We now turn our attention temporarily to the station-by-station analysis which is the more significant and critical test of the model. To facilitate the subsequent discussion, Tables 20 through 24 are first presented containing observations for, respectively, one-hour CO, eight-hour CO, 24-hour particulate, one-hour NO_2, one-hour NMHC, and 6 to 9 a.m. NMHC, average concentrations.

In view of the uncertainties regarding NO_2 and NMHC, discussed earlier, and the fact that there are data for only three stations, which limits analysis, we simply present the results in Tables 23 and 24; we note that there is generally significant overprediction, which is not at all unexpected.

Taking the particulate median values of Table 22 first, we find that the predicted and observed pairs generate a regression equation of:

$$\text{Prediction} = 0.846\ (\text{Observation}) + 28.3$$

with a correlation coefficient of 0.799, which represents significance at the one percent level, and indicates a clear ability to distinguish effects as between nearby stations.

Carbon monoxide, however, for which the dependent data predictions were uniformly good, shows an increased tendency in the independent sample to overpredict at the higher end of the distribution. This question was probed somewhat further, in order to learn, at least to some degree, the cause or causes of this. The key questions were these: was it something about the model which had seemed to perform well otherwise, or something about the sample of CO observations, that had this effect; or, possibly both were contributing.

Table 20. Statistics for CO by Stations; Independent Data Sample of One-Hour Observations Compared to GEOMET Model Prediction; mg/m^3

Station Number		n	Percentile Value							
			10%	25%	50%	75%	90%	95%	98%	Mean
1	Pred.	47	0.80	1.5	4.3	11.0	17.5	24.3	25.8	6.7
	Obs.		0.50	1.1	1.7	2.2	4.5	8.7	12.5	2.2
	Pred/Obs.		1.60	1.36	2.53	5.0	3.89	2.79	2.06	3.05
2	Pred.	66	0.91	2.0	4.8	19.9	48.3	62.3	66.9	13.9
	Obs.		0.46	0.86	1.1	1.3	2.4	2.7	2.9	1.2
	Pred/Obs.		1.98	2.33	4.36	15.3	20.1	23.1	23.1	11.6
3	Pred.	144	0.3	0.6	1.2	2.6	4.8	7.9	14.3	2.1
	Obs.		0.87	1.1	1.6	2.0	4.5	5.7	7.3	2.1
	Pred/Obs.		0.34	0.55	0.75	1.30	1.07	1.39	1.96	1.00
4	Pred.	135	0.6	1.3	2.8	5.1	9.8	14.7	22.4	4.8
	Obs.		1.2	2.0	3.4	5.5	7.1	9.3	11.4	3.9
	Pred/Obs.		0.50	0.65	0.82	0.93	1.38	1.58	1.96	1.23
5	Pred.	145	0.87	2.0	4.8	9.7	21.7	27.3	30.2	7.4
	Obs.		1.1	1.7	2.2	3.2	4.2	5.6	9.3	2.6
	Pred/Obs.		0.79	1.18	2.18	3.08	5.2	4.9	3.25	2.85
6	Pred.	96	0.33	0.67	1.2	2.2	3.2	3.5	5.3	1.6
	Obs.		0.90	1.1	1.6	2.0	2.3	2.6	3.9	1.6
	Pred/Obs.		0.37	0.61	0.75	1.1	1.39	1.35	1.36	1.00
7	Pred.	159	0.76	1.7	4.7	10.5	25.2	49.4	74.2	10.5
	Obs.		1.1	1.7	2.8	4.0	5.9	8.0	10.5	3.2
	Pred/Obs.		0.69	1.00	1.68	2.63	4.3	6.2	7.1	3.28
8	Pred.	86	0.37	0.68	1.3	4.0	7.0	9.4	16.5	2.7
	Obs.		0.90	1.1	1.7	2.5	3.4	3.9	4.8	1.9
	Pred/Obs.		0.41	0.62	0.76	1.6	2.06	2.44	3.44	1.42

Table 21. Statistics for CO by Stations; Independent Data Sample of Average Eight-Hour Observations Compared to GEOMET Model Prediction; mg/m^3

Station Number		n	Percentile Values							
			10%	25%	50%	75%	90%	95%	98%	Mean
1	Pred.	6	3.1	5.0	7.9	10.2	11.4	11.4	11.4	6.7
	Obs.		1.5	1.6	1.9	3.3	4.7	4.7	4.7	2.2
	Pred./Obs.		2.1	3.1	4.2	3.1	2.4	2.4	2.4	3.0
2	Pred.	10	3.4	3.8	7.7	25.7	29.5	29.5	29.5	12.3
	Obs.		0.8	1.0	1.2	1.8	2.1	2.1	2.1	1.2
	Pred./Obs.		4.3	3.8	6.4	14.3	14.0	14.0	14.0	10.3
3	Pred.	19	0.8	1.3	1.9	2.7	3.9	5.6	5.6	2.1
	Obs.		0.9	1.4	1.7	2.5	5.0	6.1	6.1	2.1
	Pred./Obs.		0.89	0.93	1.1	1.1	0.78	0.92	0.92	1.00
4	Pred.	18	1.5	1.9	3.3	7.2	11.4	17.5	17.5	4.6
	Obs.		1.6	2.4	3.9	5.3	5.9	6.8	6.8	3.6
	Pred./Obs.		0.94	0.79	0.85	1.4	1.9	2.6	2.6	1.3
5	Pred.	19	2.7	3.7	6.4	11.4	14.9	15.0	15.0	7.3
	Obs.		1.4	1.9	2.4	3.1	3.9	5.3	5.3	2.5
	Pred./Obs.		1.9	1.9	2.7	3.7	3.8	2.8	2.8	2.9
6	Pred.	12	0.8	1.2	1.5	2.1	2.9	2.9	2.9	1.6
	Obs.		1.1	1.5	1.7	1.9	2.2	2.2	2.2	1.6
	Pred./Obs.		0.73	0.80	0.88	1.1	1.3	1.3	1.3	1.00
7	Pred.	21	2.5	4.2	6.7	13.1	30.2	38.9	38.9	10.4
	Obs.		1.3	2.1	2.8	3.8	5.9	6.3	6.3	3.1
	Pred./Obs.		1.92	2.0	2.4	3.4	5.1	6.2	6.2	3.4
8	Pred.	11	1.0	1.4	3.3	3.6	4.7	4.8	4.8	2.7
	Obs.		1.2	1.4	1.9	2.2	3.4	3.5	3.5	1.9
	Pred./Obs.		0.83	1.00	1.7	1.6	1.4	1.4	1.4	1.4

Table 22. Statistics for Particulates by Stations; Independent Data Sample of Average 24-Hour Observations Compared to GEOMET Model Predications ug/m^3

Station Number		Percentile Value								
		n	10%	25%	50%	75%	90%	95%	98%	Mean
1	Pred.	4	76	80	91	141	141	141	141	96
	Obs.		52	58	67	102	102	102	102	69
	Pred/Obs.		1.46	1.38	1.36	1.38	1.38	1.38	1.38	1.39
2	Pred.	22	57	81	102	129	151	157	157	100
	Obs.		55	65	82	114	134	138	138	86
	Pred/Obs.		1.04	1.25	1.26	1.13	1.13	1.14	1.14	1.16
3	Pred.	21	43	46	55	64	88	135	137	59
	Obs.		39	41	51	66	89	98	98	55
	Pred/Obs.		1.10	1.12	1.08	0.97	0.99	1.38	1.38	1.07
4	Pred.	10	68	83	112	147	149	149	149	104
	Obs.		62	83	92	112	128	128	128	91
	Pred/Obs.		1.10	1.00	1.22	1.31	1.16	1.16	1.16	1.14
5	Pred.	11	62	82	94	120	177	180	180	99
	Obs.		53	65	67	90	112	113	113	74
	Pred/Obs.		1.17	1.26	1.4	1.33	1.6	1.6	1.6	1.34
6	Pred.	18	46	49	61	73	89	107	107	62
	Obs.		43	48	57	75	107	136	136	63
	Pred/Obs.		1.07	1.02	1.07	0.97	0.83	0.79	0.79	0.98
7	Pred.	11	60	84	125	194	400	415	415	147
	Obs.		59	93	126	147	216	223	223	120
	Pred/Obs.		1.02	0.90	0.99	1.32	1.85	1.86	1.86	1.23
8	Pred.	6	61	72	96	128	140	140	140	90
	Obs.		53	56	62	91	113	113	113	67
	Pred./Obs.		1.15	1.29	1.55	1.41	1.24	1.24	1.24	1.34

Table 23. Statistics for NO_2 by Stations; Independent Data Sample of One-Hour Observations Compared to GEOMET Model Prediction; mg/m^3.

Station Number		n	Percentile Values							
			10%	25%	50%	75%	90%	95%	98%	Mean
2	Pred. Obs. Pred/Obs.	108	0.08 0.05 1.6	0.20 0.08 2.5	0.48 0.14 3.4	1.23 0.26 4.7	2.88 0.38 7.6	3.86 0.45 8.6	8.72 0.47 18.6	1.08 0.18 6.0
3	Pred. Obs. Pred/Obs.	106	0.03 0.05 0.6	0.07 0.07 1.0	0.21 0.11 1.9	0.47 0.19 2.5	1.36 0.36 3.8	2.62 0.43 6.1	6.08 0.57 11.7	0.56 0.15 3.7
6	Pred. Obs. Pred/Obs.	38	0.02 0.03 0.67	0.09 0.05 1.8	0.22 0.09 2.4	0.56 0.24 2.3	3.05 0.30 10.2	4.53 0.38 11.9	7.08 0.52 13.6	0.82 0.14 5.9

Table 24. Statistics for Non-methane Hydrocarbons by Stations; Independent Data Sample of Observations Compared to GEOMET Model Prediction; $\mu g/m^3$.

One-Hour Observations										
Station Number		n	Percentile Values							
			10%	25%	50%	75%	90%	95%	98%	Mean
2	Pred. Obs. Pred/Obs.	146	156 0.0 -	281 0.0 -	685 174 3.9	1912 384 5.0	3187 745 4.3	4366 1107 3.9	5963 1416 4.2	1333 208 5.0
3	Pred. Obs. Pred/Obs.	201	48 0.0 -	99 2.9 3.4	207 122 1.7	353 256 1.4	533 473 1.1	954 560 1.7	1287 1119 1.2	280 192 1.5
6	Pred. Obs. Pred/Obs.	151	55 723 0.1	101 1054 0.1	192 1333 0.1	348 1605 0.2	551 1949 0.3	824 2050 0.4	1808 3205 0.6	272 1354 0.2
6 - 9am Average Observations										
2	Pred. Obs. Pred/Obs.	77	184 0.0 -	386 0.0 -	1063 15 71	2191 265 8.3	3255 551 5.9	3682 918 4.0	4700 1377 3.3	1421 173 8.2
3	Pred. Obs. Pred/Obs.	77	84 0.0 -	152 15 10.1	231 117 2.0	327 213 1.5	615 399 1.5	753 485 1.6	1004 1319 0.8	282 167 1.7
6	Pred. Obs. Pred/Obs.	77	115 0.0 -	162 0.0 -	300 1105 0.3	417 1452 0.3	596 1659 0.4	924 1915 0.5	1004 2844 0.4	328 894 0.4

Presenting our conclusion in advance, we believe that there is a contribution from both causes, but a greater one from the sampling, and briefly will present our reasons. First, as to the model's tendency to overpredict: limited inspection of individual high one-hour cases, and of stations near traveled roads, has indicated that this overprediction can most often occur when one or more of the line sources representing roads in the model is parallel to the input steady-state wind direction, and the receptor being calculated is near the downwind end of the road segment (the taxiway and the runway line sources do not show this effect in the WNA context because significantly lower emissions are involved). Inspection of Table 20, and Figures 1 and 24, shows that this effect is present, as expected, in Stations 2, 5 and 7 (near roads) and absent in 3, 4, 6 and 8. These latter stations, by the way, show up especially well in the critical central portion of the distribution (the 25th to the 75th percentile range). The problem emphasized by Stations 2, 5 and 7 is comparable to the well-known case in general diffusion calculations when a receptor is close to a point source of high emission rate. Wind direction, and degree of steady stateness is critical in that instance, and apparently can be in the line source calculations of the airport model as well. No ready physical or mathematical resolution to the steady-state modeling problem here has yet come to mind; further study is required. However, as an interim expedient, rectifying the resulting distribution of predicted short-term concentrations may be manageable by recourse to Larsen's* technique of generating the equivalent log-normal distribution (which he uses to solve the problem of questionable or unrepresentative reported values at the high end of the distribution). His approach focuses on use of the distributional values (observed or predicted) in the 50th to 84th percentile range, usually a fairly representative and stable portion of the distribution. This may well warrant further investigation in applications of the developed model.

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*Larsen, R. I., 1971. A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards. EPA Office of Air Programs; Publication No. AP-89.

We next must address ourselves to the other potential cause of analytical difficulty, that of the representativeness of the independent data sample selected. While it should not matter theoretically whether the distribution of observations selected adequately represents the total distribution, the characteristics of the steady-state model are such they better predict average, or representative concentrations. Thus, if the input data on emissions, aircraft, and automobile activity, and meteorological conditions are adequately representative of the total spectrum of conditions, but for some reason the associated observed CO pollutant concentrations are non-representative (a low probability, but still possible), then the model is laboring under an unfair handicap in trying to reproduce such an unrepresentative distribution. Evidence thus far in our discussion that this may be the case is in the fact that the CO and particulates both validated well with the dependent sample, and the particulate validation improved with the independent sample, while for CO it worsened. The effect of any tendency to overpredict for single hour predictions would be lessened, of course, for the 24-hour averages of particulates by the averaging process itself.

To examine the possible non-representativeness of the independent CO sample of verification observations, we can look at it in comparison to the total CO data sample, and to the dependent sample. This is done in Figure 41, which is plotted on a variation on the log-normal graph used previously, and emphasizes the upper end of the distribution. We see that a real difference appears between the independent sample distribution and both the total observed sample and the dependent sample. The total sample of course includes both the others. The peculiarity is seen when we observe that the dependent sample (180 values) includes a maximum of about 35 mg/m^3, and has one percent of its values greater than 17 mg/m^3. The total sample (n = 21,260) has a maximum of 88 mg/m^3, with one percent of its values greater than 15 mg/m^3; thus the 99th percentiles are quite comparable (17 versus 15 mg/m^3). The independent sample (n = 878, or almost five times the dependent sample) has a maximum value of only about 16 mg/m^3, and the 99th percentile is only 9.8 mg/m^3 (compared to 17 and

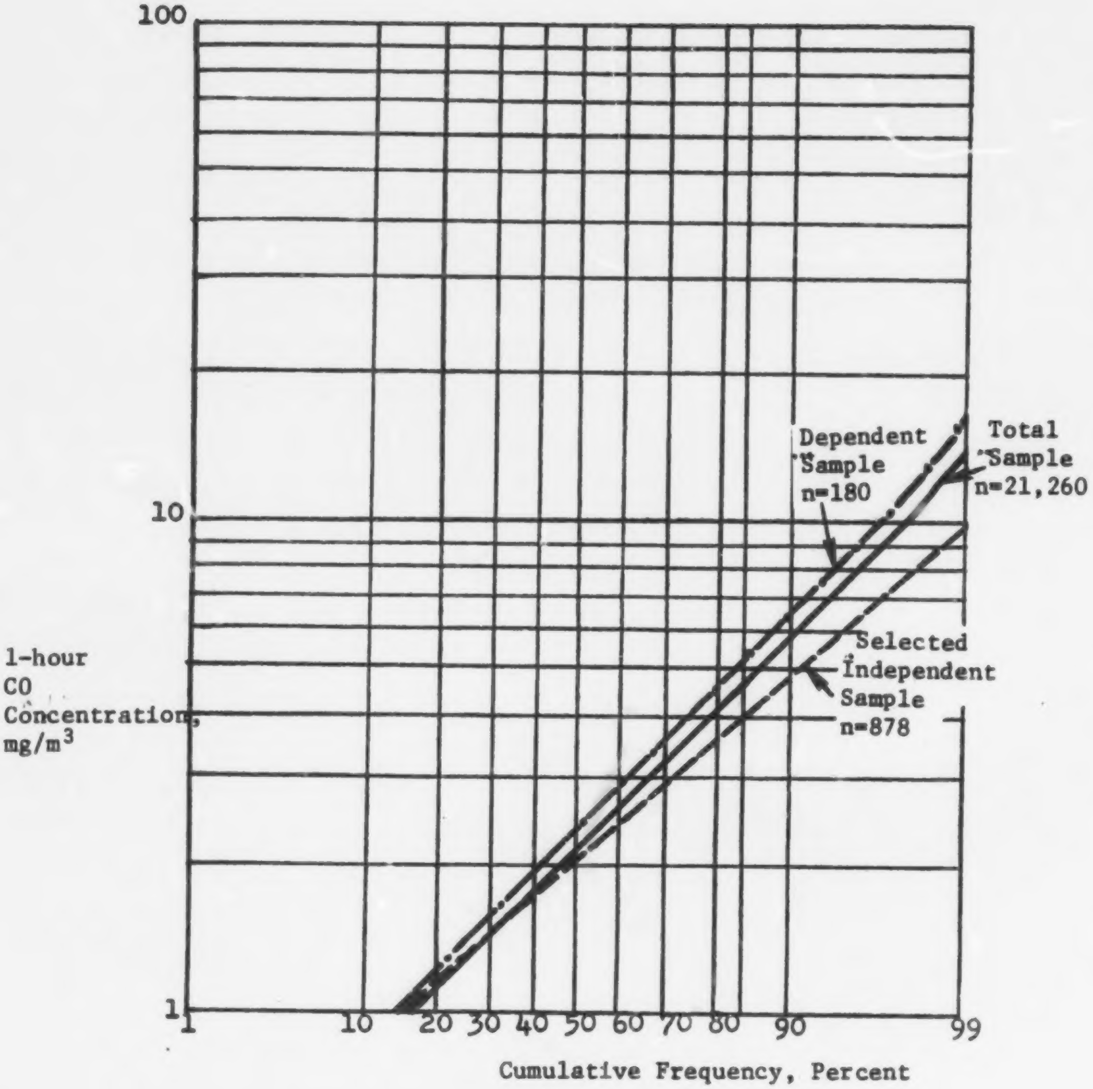

Figure 41. Comparison of 1-Hour CO Observational Data Distributions

15, above). How such an unrepresentative sample could have come about is not known, in view of our efforts to distribute independent sample selection properly through the period; nonetheless it apparently did occur, and it is our conviction that a better comparison, at least distribution-wise, can be made between the total predictions and the total observations.

It is unfortunate that both of our problems arose simultaneously, and tended to confound each other. That is, the real tendency to overprediction at higher values for receptor stations near roads would raise the higher end of the predicted distribution, while the non-representativeness of the sample produces an observed distribution much lower in the high percentiles.

Barring a complete repeat of the prediction using a new independent sample, obviously not feasible as we neared completion of the project, the next best method of comparing predicted and observed CO distributions was to compare the entire set of 1408 CO predictions with the entire set of 21,260 CO observations.* This, of course, does not resolve the problem of the calculated high values from steady winds along line sources, but it more clearly defines the model's present capability for one-hour CO predictions, and gives more acceptable and representative validation procedures, as seen below. This process, thus somewhat laboriously described and justified in the preceding material, results in the tabular comparison shown in Table 25, and enables us shortly to go on to the next section, which describes some uses of the model.

The table is in fact a comparison between the two sets of paired data: first, the selected sample of independent predictions against (and matching in number) the independent sample of observations (now possibly unrepresentative, as discussed previously); and second, the total sample of independent

---

*The use of statistically selected samples of complete distributions, to represent the total distribution of either observed or predicted values, has been extensively studied at GEOMET (see Koch and Fisher, 1973).

TABLE 25. ONE-HOUR AVERAGE CO CONCENTRATIONS: STATISTICS OF THE PREDICTIONS AS FRACTIONS OF THE CORRESPONDING STATISTICS OF THE OBSERVATIONS

Station	Median (Predicted/Observed)		Mean (Predicted/Observed)		98th Percentile*** (Predicted/Observed)	
	Selected*	Total**	Selected*	Total**	Selected*	Total**
1	2.50	1.66	3.00	1.66	2.06	2.28
2	4.3	2.97	11.7	5.49	23.4	6.46
3	0.57	0.82	1.00	1.05	1.95	2.24
4	0.84	0.63	1.25	0.90	1.97	1.13
5	2.2	1.38	2.86	2.21	3.24	3.88
6	0.74	0.98	0.96	1.52	1.40	3.34
7	1.66	1.62	3.26	2.00	7.07	1.06
8	0.76	0.99	1.42	1.66	3.46	2.11

*As described in the text, the "selected" columns represent comparison of the selected sample of independent predictions against the matching set of the independent sample of observations (in question as discussed in the text).

**The columns headed "total" show the comparisons of the total set of independent predictions with the total set of observations.

***We use the 98th percentile here as a more representative and more stable statistic than the single maximum value, again following Larsen's suggestion. The percentile value selected is arbitrary.

predictions against the total data set. For each of the three statistics (median, mean, and 98th percentile), improvement is shown (the predicted/observed ratio moves closer to unity) as we move from the "selected" comparison column to the "total" column. The improvement is general, even significant, in some cases, especially at Stations 2 and 7, and ranges down to no change, or slight worsening in a few cases (the median at Station 4, and the median and 98th percentile at Station 6).

Regression analysis on the medians gives the following comparison equations, which show the general improvement in prediction.

For the "selected" case:

$$\text{Prediction} = 0.373\ (\text{Observation}) + 2.38;\ r = 0.171$$

For the "total" case:

$$\text{Prediction} = 0.578\ (\text{Observation}) + 1.39;\ r = 0.396$$

The coefficient of the linear term rises toward unity, as we would like; the intercept of the regression line similarly reduces toward zero; and the coefficient of correlation improves. The implication is that the predictions represent an improved sample of the total distribution. The overall results still leave something to be desired however, presumably because of the problem with Stations 2, 5 and 7 described above.

Incidentally, a similar analysis performed on the particulate geometric means (presented previously for the "selected" data sample), produced the following change in the resulting regression equation.

For the "selected" case (presented previously):

$$\text{Prediction} = 0.846\ (\text{Observation}) + 28.3;\ r = 0.799$$

For the "total" case:

$$\text{Prediction} = 0.993\ (\text{Observation}) + 5.7;\ r = 0.798$$

The already high correlation coefficient can hardly be improved, and represents significance at the one percent level. However, the approach of the coefficient of the linear term to almost unity, and of the intercept of the regression line to near zero, is highly satisfactory. The inference could also be drawn from this (but it would be unjustified), that one is more likely to obtain a good representation of the total observations by making a reasonably large set of predictions with this model, than by taking a similar sample of the observations themselves, which as we have seen, has a greater risk of being unrepresentative.

We recall, however, that we can still encounter difficulties in overprediction at the high end of the distribution, and so we go on to the subject of uses of the model with some confidence, but with caution when considering short-term maximum values.

Utility of the GEOMET Model

The objective of this model development work is to generate a model which can be adequately validated, and, having done this, to employ the model in various ways to study the contributions of various airport (aircraft and non-aircraft) and non-airport emission sources to air pollution concentrations in and near airports.

To this end, the model is designed to store and printout concentration contributions in various ways. A few small samples of the most important ones are shown in Tables 26 and 27. The first of these demonstrates, for one pollutant (CO) and one receptor (Station 1), the printout by hour of the contributions from each source type (terminals, runways, taxiways, roadways, heat and fuel (heating and power plants), area sources, and peripheral highways), and the total concentration for each hour for which calculation is made. In the table, the first column is a date-time group (72326 = 1972,326th day by the Julian Calendar, or 21 November 1972), and the second column the beginning of the hour (100 = 0100 or 1 a.m.); the hour being predicted for is thus 1 to 2 a.m. The succeeding seven columns give the concentration contributions in grams per m^3 for each source type as indicated, and the final column gives the total predicted concentration for that station-hour-pollutant.

Table 26. Independent Data Sample Predictions For Carbon Monoxide (g/m^3), For Receptor Number 1 And Pollutant Carbon Monoxide

		Terminals	Runways	Taxiways	Road-ways	Heat & Fuel	Areas	Highways	Totals
72326	100	0.0	0.6738E-05	0.2335E-04	0.0	0.0	0.2256E-02	0.4162E-04	0.2328E-02
72326	200	0.0	0.1618E-05	0.2556E-05	0.0	0.0	0.7921E-02	0.4444E-04	0.7969E-02
72326	300	0.0	0.2061E-05	0.5491E-05	0.0	0.0	0.9079E-05	0.3259E-04	0.4922E-04
72326	400	0.0	0.2905E-05	0.7738E-05	0.0	0.0	0.1279E-04	0.4592E-04	0.6936E-04
72326	500	0.0	0.2595E-05	0.6913E-05	0.0	0.0	0.1143E-04	0.1477E-03	0.1686E-03
72326	600	0.0	0.4870E-05	0.1257E-04	0.0	0.0	0.1862E-05	0.7265E-03	0.7458E-03
72326	700	0.0	0.6255E-04	0.1251E-03	0.0	0.0	0.1677E-03	0.7418E-03	0.1097E-02
72326	800	0.0	0.6051E-04	0.5971E-04	0.0	0.0	0.2131E-02	0.2896E-03	0.2541E-02

Table 27. Statistics For Receptor Number 1 And Pollutant Carbon Monoxide For The Totals (mg/m^3)

Mean = 4.1111
Standard Deviation = 4.7556
Skewness = 2.4679

Kurtosis = 6.7653
Error = 0

The Percentile Values Are:

1%	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
0.07	0.13	0.26	0.43	0.67	0.85	1.10	1.42	1.83	2.05	2.31	2.83

55%	60%	65%	70%	75%	80%	85%	90%	95%	97%	98%	99%
3.19	3.55	3.94	4.32	4.81	5.90	7.01	9.76	14.83	20.22	22.95	25.05

With The Lowest Value Of 0.05 And The Highest Value Of 25.68 Out Of 176 Values.

The Following Statistics Are For Receptor Number 1 And Pollutant Carbon Monoxide For The Terminals

Mean = 0.6631
Standard Deviation = 1.8340
Skewness = 3.9907

Kurtosis = 17.4122
Error = 0

The Percentile Values Are:

1%	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00

55%	60%	65%	70%	75%	80%	85%	90%	95%	97%	98%	99%
0.00	0.00	0.02	0.06	0.25	0.60	0.98	2.18	4.74	7.09	8.41	10.83

With The Lowest Value Of 0.0 And The Highest Value Of 12.51 Out Of 176 Values.

The Following Statistics Are For Receptor Number 1 And Pollutant Carbon Monoxide For The Runways

Mean = 0.0292
Standard Deviation = 0.0537
Skewness = 2.3244

Kurtosis = 5.1123
Error = 0

The Percentile Values Are:

1%	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

55%	60%	65%	70%	75%	80%	85%	90%	95%	97%	98%	99%
0.00	0.00	0.02	0.02	0.04	0.05	0.07	0.10	0.17	0.21	0.23	0.24

With The Lowest Value Of 0.0 And The Highest Value Of 0.25 Out Of 176 Values.

Six pages like this one contain the 176 independent sample CO predictions for Station 1 which were employed as part of the preceding section's work on validation. In that section, however, only the final column of total predicted concentrations was used. The other seven columns would now come into use in the application of the model.

The incremental and total concentrations are summarized statistically by station (and in cumulative fashion for all station-receptors, if desired), for the pollutant of concern. An example is Table 27. In these summaries the standard computer concentration units of g/m^3 are converted to those customarily seen for the pollutant being considered; in this case, for CO, the units are mg/m^3.

Table 27 is one of these statistical summaries for Station 1 for CO, in this case the same data as in the previous table and including all 176 hours, rather than the eight shown in Table 26. The statistics are given for the totals, terminals and runways only, and not the other five sources.

In Table 27, first the statistics and distribution of the first table's column of "total" concentration are given; this is followed in turn by a similar summary for each of the contributing sources, starting with terminals from the left-most column of the first table through to the highways as the last listed contributor.

These two types of summaries, the listing out hour-by-hour of each set of incremental and total concentrations, and the statistical summaries, may be used in a variety of analytical ways to study airport air pollution. The contributions to concentrations may be broken down into further detail, or may be aggregated, by simple program adjustments. We show these tables simply as examples of some of the many data bases which can be developed for use in airport pollution analyses.

Interesting to note, in all the summaries mentioned above, and exemplified in the final table just discussed, is the finding that, at Washington National Airport, the contributions of aircraft and other airport-related sources make up only a very small fraction of the total air pollution burden in the airport vicinity. By far the greater contributions come from the surrounding major highways and environ area sources.

Such analyses are not properly part of this project, and are cited here as examples only. However, another implication of this finding lies in the fact that the aircraft and airport contributions are the most important elements for this model study; if they are very small fractions of the measured total concentrations, or only make significant contributions rarely, then even though we have validated against those totals, we cannot yet be sure that we have adequately modeled the aircraft and airport segments of the model; nonetheless, the basic principles have been demonstrated, and we believe the model is sound for the aircraft and airport details as well. There is still a need for validation at one or more other airports, most preferably, at the least, at one for which the airport generated pollutants are not as largely masked as they are at Washington National Airport.

SECTION VI

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APPENDIX A

Figures 1 through 9 provide the wind rose data for the months of October through June. The data represent observations made by the U.S. Weather Bureau over a 10-year period.*

The wind rose data show the prevailing winds from each of the quadrants to be as follows:

From the NE quadrant: 20%
From the SE quadrant: 12%
From the SW quadrant: 32%
From the NW quadrant: 31%

Calm is recorded about 5 percent of the time.

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* U.S. Weather Bureau. Decennial Census of United States Climate, Washington, D.C. National Airport 1951-1960. Climatology of the United States No. 82-50.

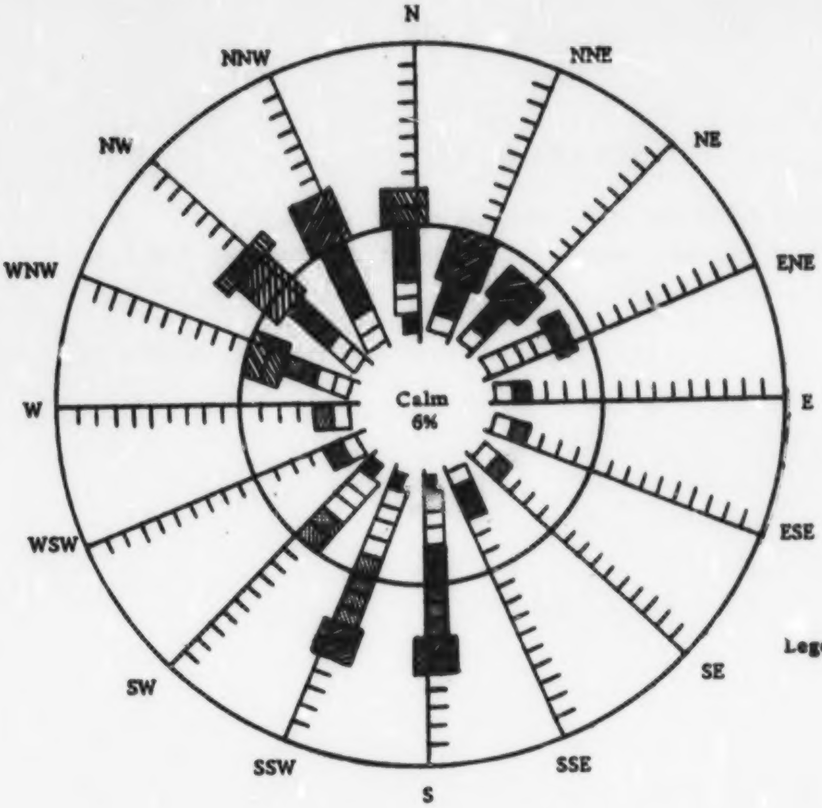


Figure 1. Wind Rose - Washington National Airport - October

Legend:

MPH

▭ 25 - 31
▥ 19 - 24
▨ 13 - 18
▩ 8 - 12
▭ 4 - 7
■ C - 3

Each increment on a radial is 1%

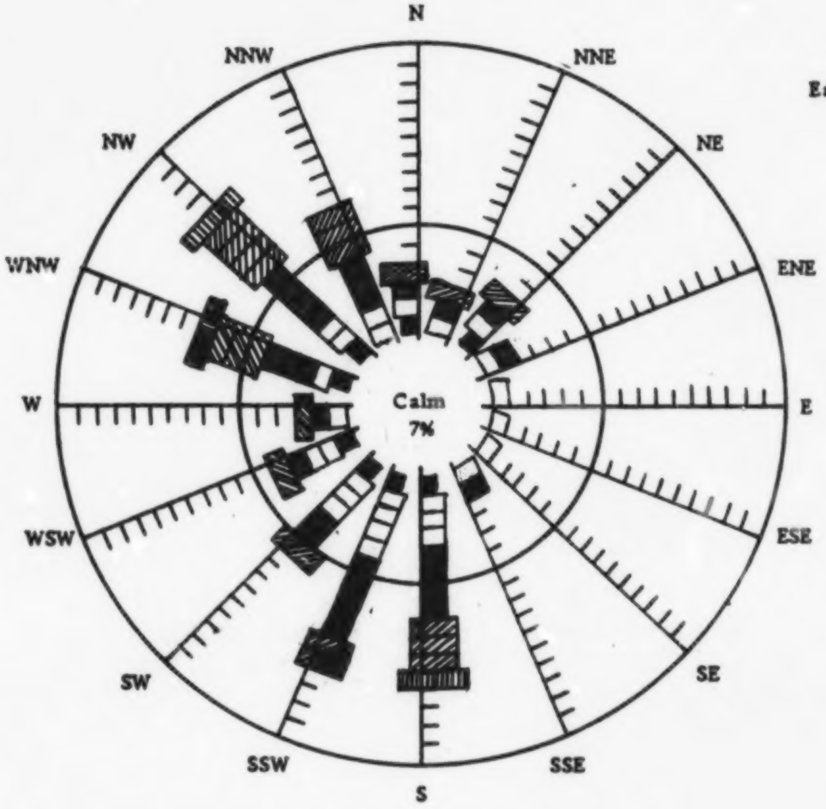


Figure 2. Wind Rose - Washington National Airport - November

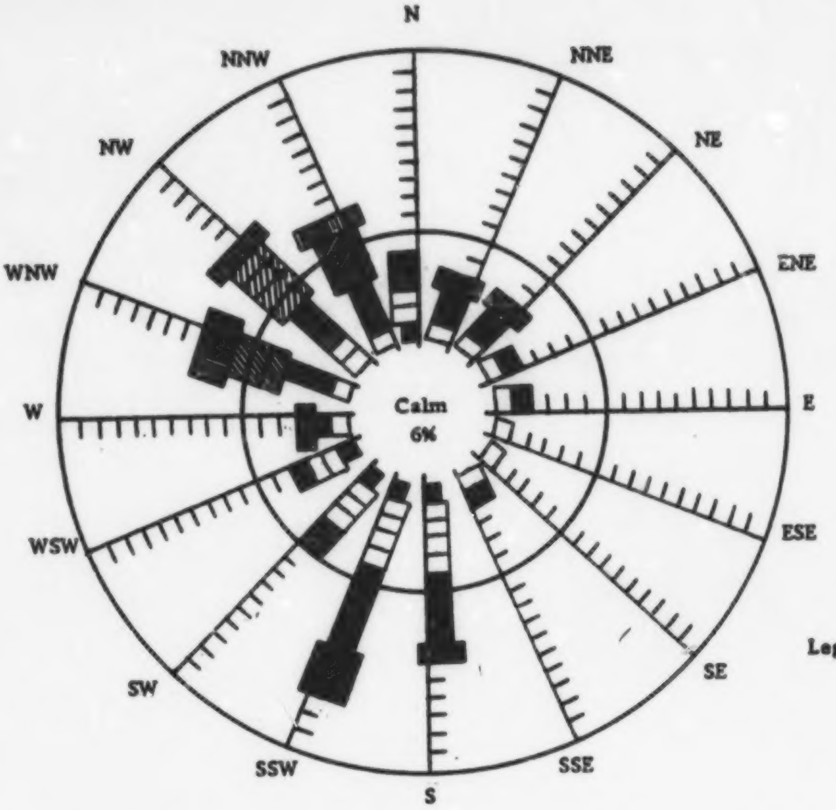
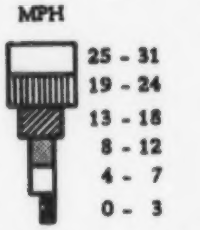


Figure 3. Wind Rose - Washington National Airport - December

Legend:



Each increment on a radial is 1%

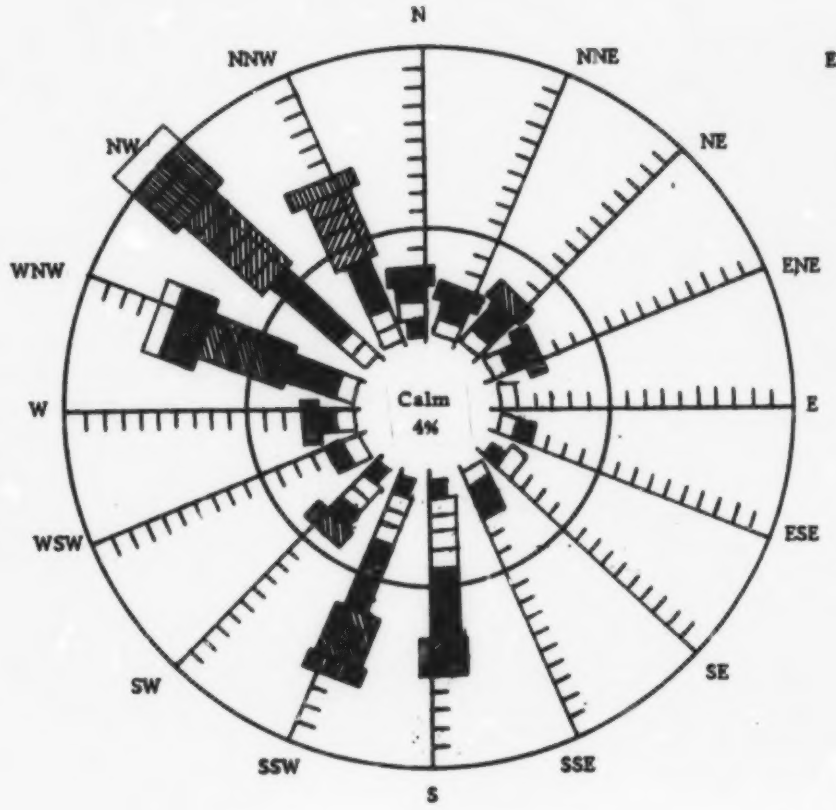


Figure 4. Wind Rose - Washington National Airport - January

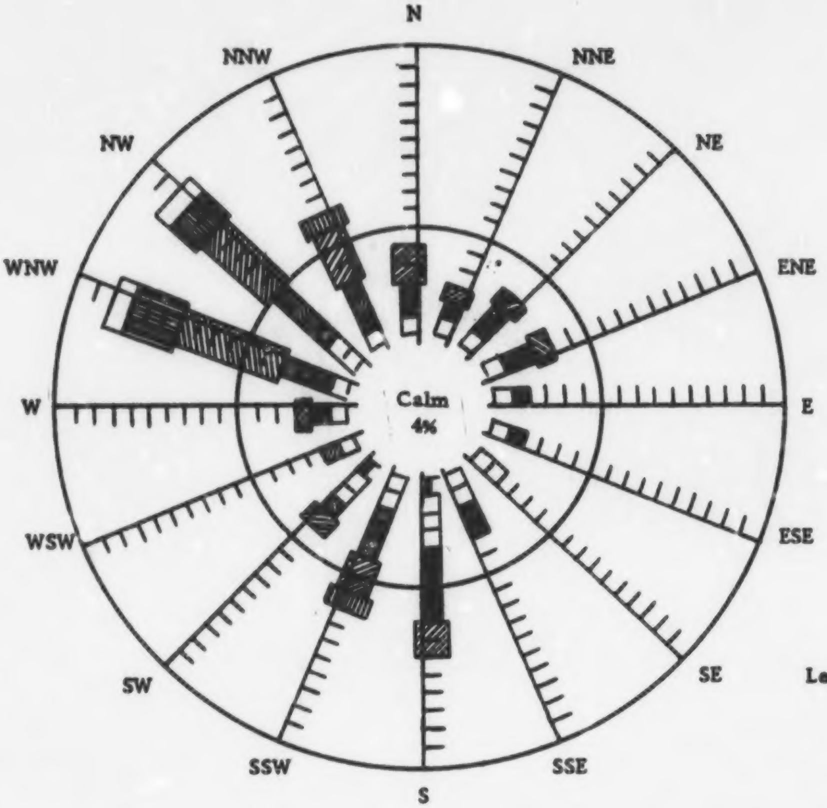


Figure 5. Wind Rose - Washington National Airport - February

Legend:

MPH

□ 25 - 31
▥ 19 - 24
▨ 13 - 18
▩ 8 - 12
□ 4 - 7
■ 0 - 3

Each increment on a radial is 1%

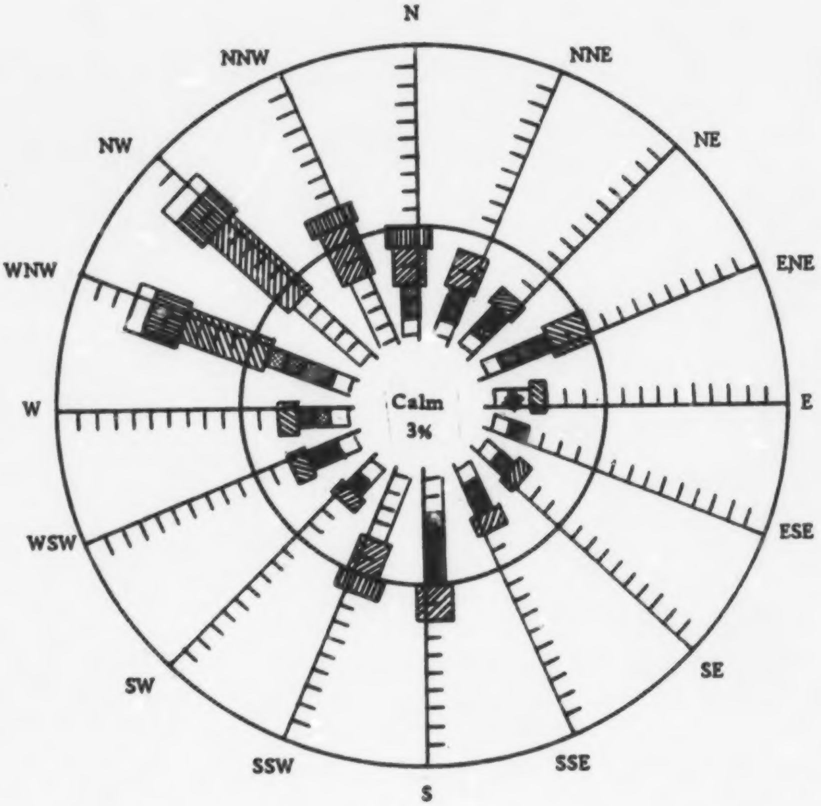


Figure 6. Wind Rose - Washington National Airport - March

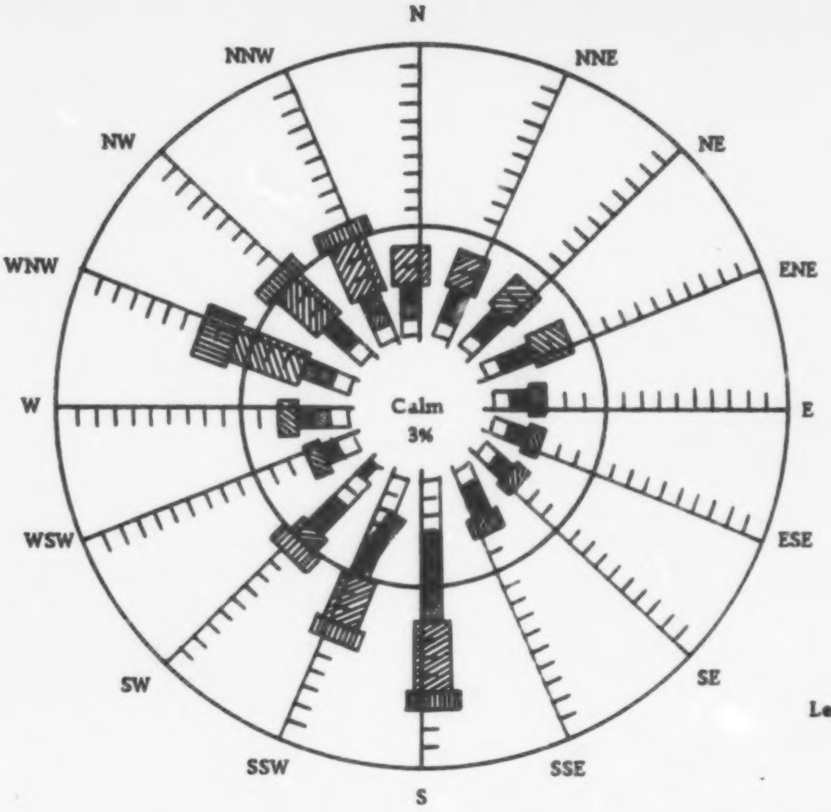
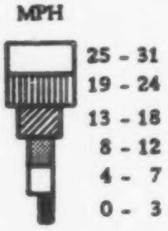


Figure 7. Wind Rose - Washington National Airport - April

Legend:



Each increment on a radial is 1%

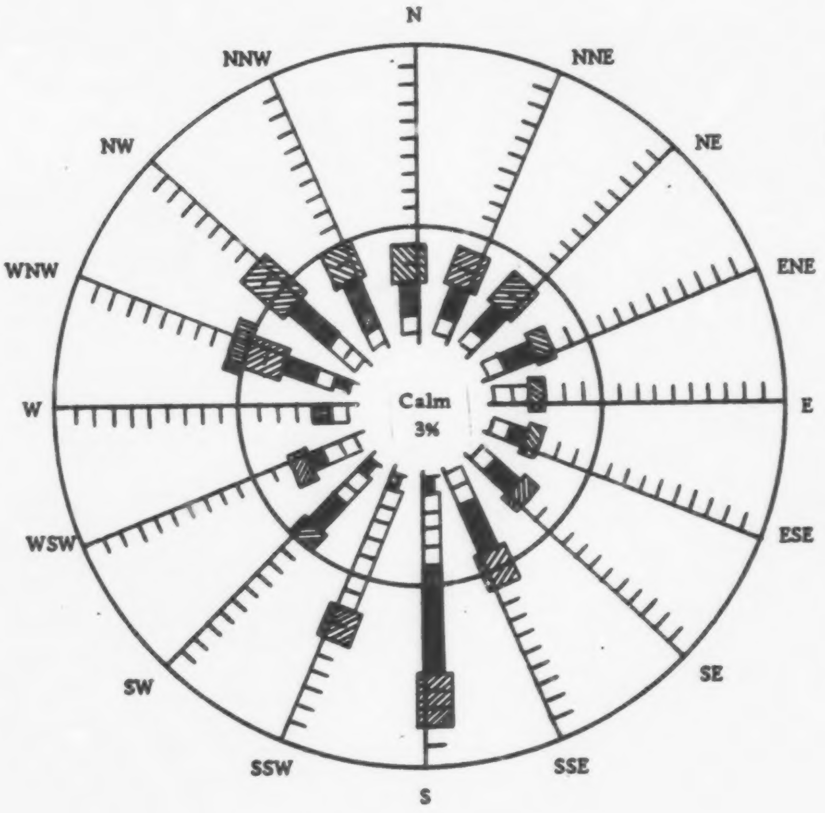


Figure 8. Wind Rose - Washington National Airport - May

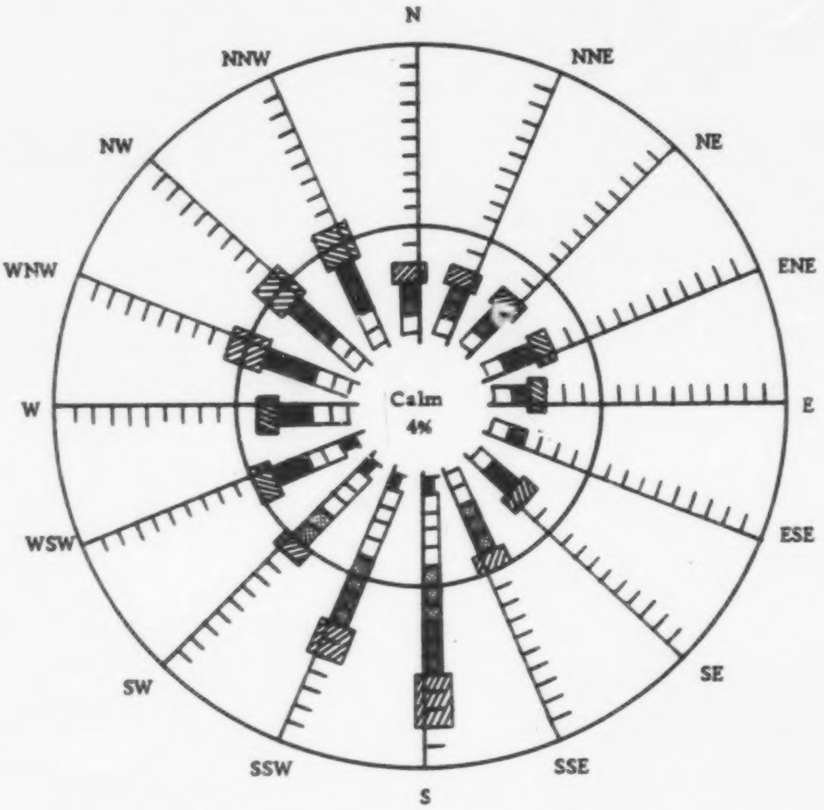


Figure 9. Wind Rose - Washington National Airport - June

Legend:

MPH

□ 25 - 31
▥ 19 - 24
▨ 13 - 18
▦ 8 - 12
□ 4 - 7
■ 0 - 3

Each increment on a radial is 1%

APPENDIX B

The availability of Thermasonde sounding data prior to April, together with periodic radiosonde sounding data, has permitted certain comparative analyses to determine whether similar results are obtained from the two systems. In addition, the Thermasonde data are interpretable by two methods of analysis. Knowledge of the interrelations between radiosonde and Thermasonde data are important, because the Thermasonde gives us hourly direct measurements of temperature gradient with height during its months of operation, but only twice-daily, radiosonde sounding data are available during the early part of the measurement period, and during the final month. These were obtained from the Environmental Meteorological Support Unit at Washington National Airport.

Initial work with the Thermasonde analysis has been to compare the two obtainable sounding profiles (overlay and applicable height methods) from the analyzed traces with each other, and with the radiosonde sounding profiles from Washington National Airport when available. The following discussions cover important aspects of interpretation of the Thermasonde data, and comparisons of these data with the radiosonde data. Complete results of such comparisons will be given in the final report. Analysis of the Thermasonde traces is being done using two methods of analysis: 1) the overlay method and 2) the applicable height methods.

The overlay method consists of matching the trace, produced on chart paper during each sounding, to the most appropriate selected copy from a library of traces which represent a variety of temperature profiles. When a trace from the catalog matches that produced by the Thermasonde, a temperature profile can be found in the catalog using the reference number of the selected overlay trace.

This method has the disadvantage of being both subjective and time consuming, especially when there are no traces in the catalog which reasonably well fit the trace from the sounding. When no single overlay trace fits the sounding trace, then a composite of fits is attempted, using portions of curves from the overlay catalog which match sections of the sounding trace. Patching a composite of traces together is difficult because the altitude of any portion of a trace is not well defined. Consequently, any departures between the overlay trace and the sounding trace require an estimate both of the altitude where the departure begins, and also of the magnitude of the departure.

The most frequent discrepancy between overlay profiles and radiosonde soundings occurs in the layer from the surface to about 500 meters in altitude. Here the surface inversion (from the radiosonde) is frequently much stronger than represented by the catalog traces, or the lapse rate near the surface is greater than depicted by traces in the catalog. Where such discrepancies exist, the applicable height method generally more nearly approximates the radiosonde sounding in the first 300-500 meters. Conversely, however, the overlay technique will pick up radiosonde-indicated inversions at higher elevations, which the applicable height method will show only as modest changes in temperature gradient.

The applicable height method uses an algorithm to calculate the temperature-height profile. This converts tracing indicators of height and temperature, through a formula developed by Sperry-Rand, to "true" temperature-height profiles, by relating the elements of the tracing to reference temperature (surface) and ambient pressure. This method is more objective in implementation, compared to the overlay method and, as indicated above, is more consistent with the radiosonde sounding in the range of 300-500m and below, but not above that height range.

APPENDIX C

During the intensive study period in April five grab sampling locations were selected along the ramp side of the terminal and hangar buildings as shown in Figure 10 and described as follows:

GI - at the general aviation terminal
GII - fire house number 1
GIII - at gate 20 near the center of the main terminal building
GIV - half way out the TWA/NW airlines finger
GV - at hangar V

Figure 11 shows the times during April and May when the activities of the intensive study period were being conducted. Several samples at each location were taken in sequence.

The time of sample collection and the concentration analyzed from each sample is shown in Figures 12 to 15. Those figures show that the CO concentrations run about 2 to 4ppm most of the time during the grab sampling periods.

All of the grab samples were analyzed using the Byron gas chromatograph (GC). Several of the grab samples were also analyzed with the MSA analyzer after using the chromatograph.

Table 1 lists the comparative data which were thus obtained. The MSA result is higher than the GC reading in all cases, the absolute differences ranging from 0.2 to 2.6ppm, and the percentage differences (compared to the MSA value) ranging from 10 to 60 percent. There is an indication of a tendency for the difference to be dependent on the magnitude of the MSA value; no explanation for the difference has been developed as yet, from the sampling and measurement method, the instruments, or the calibrations (the same calibration span gas, giving a value of 83ppm, showed about 2 percent difference between the instruments).

Table 2 lists the wind speeds and directions recorded during the grab sampling periods.

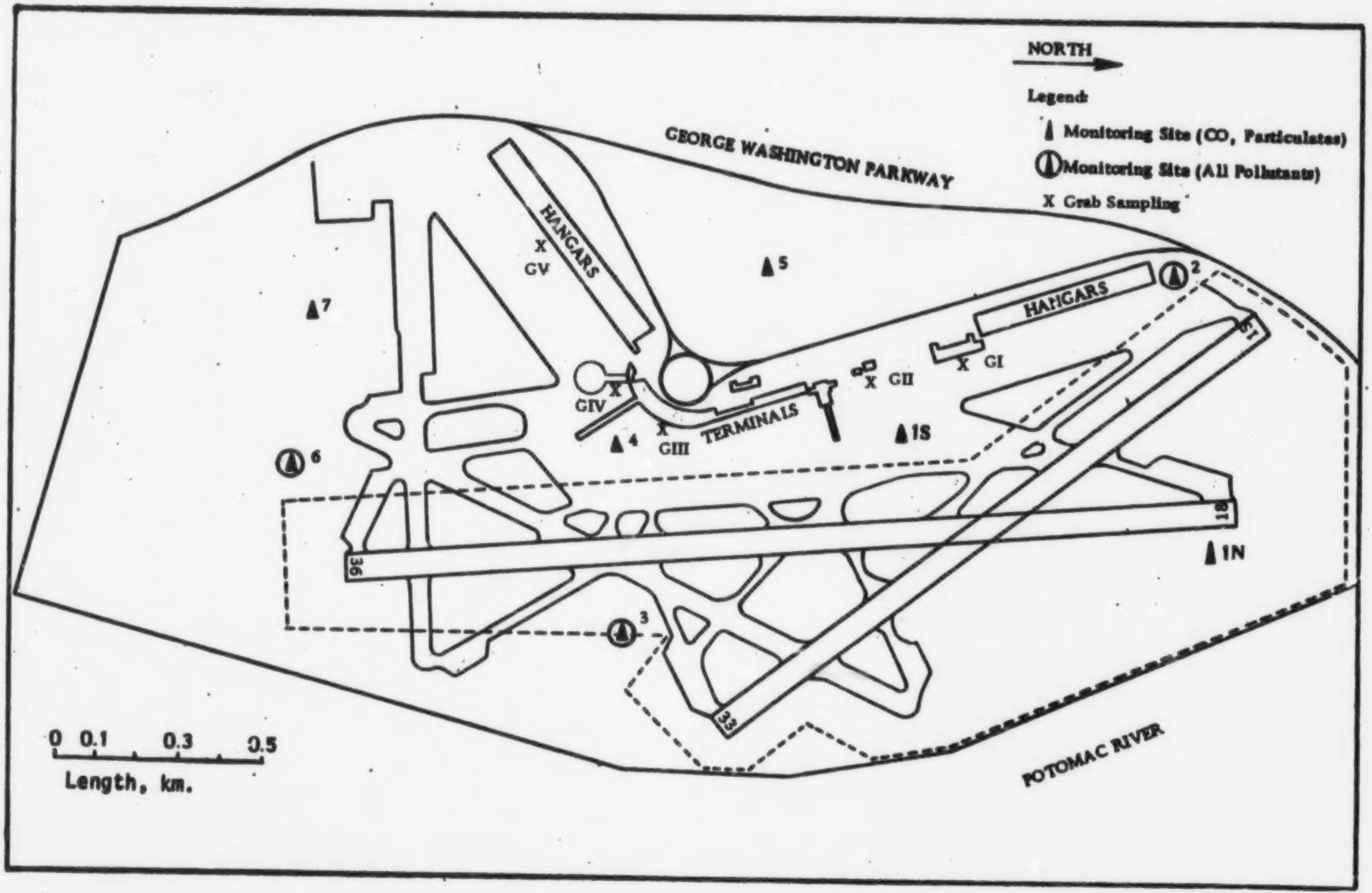


Figure 10. Grab Sample Locations

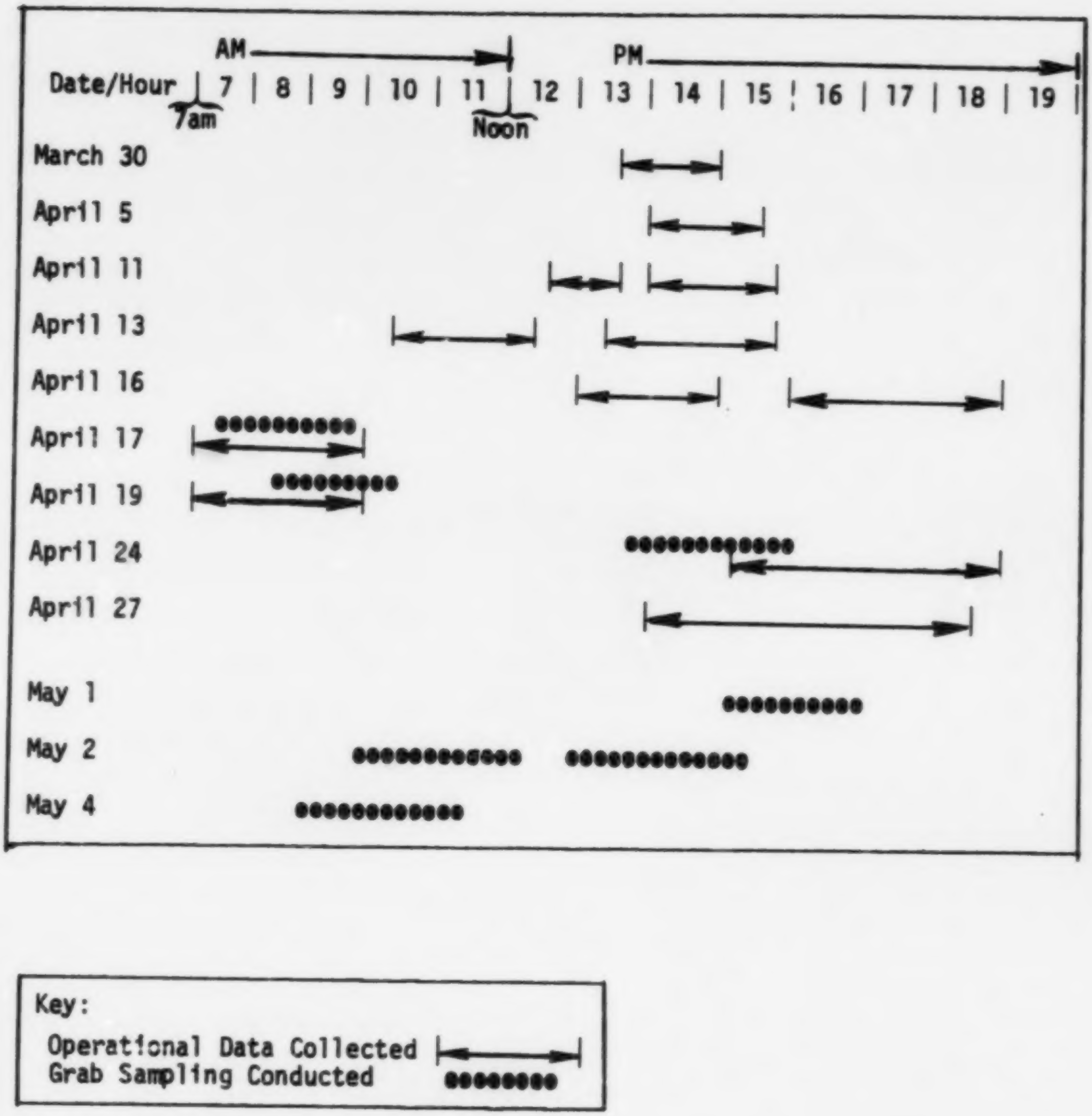


Figure 11. Intensive Study Period Recording Hours

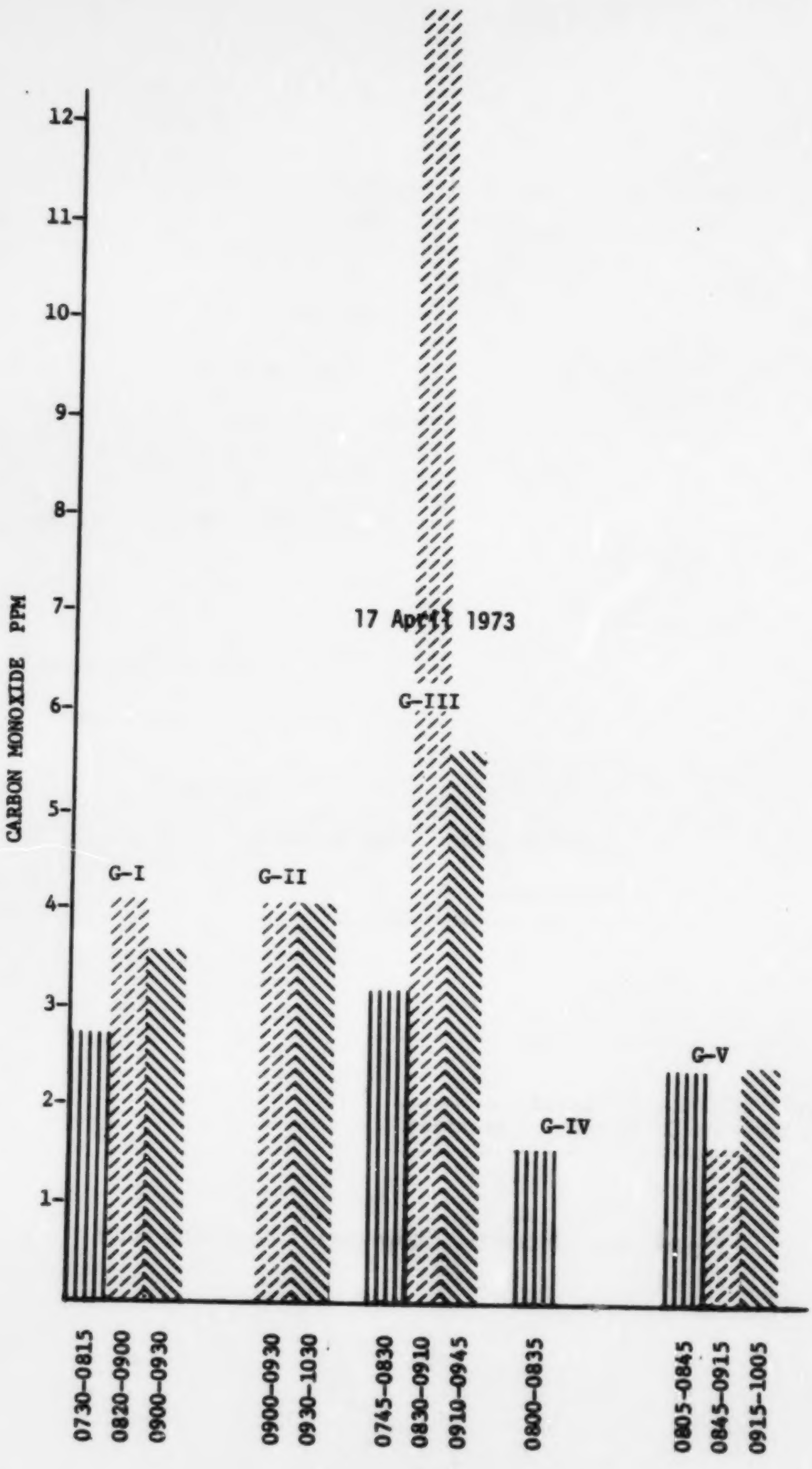


Figure 12. Grab Sample Results April 17

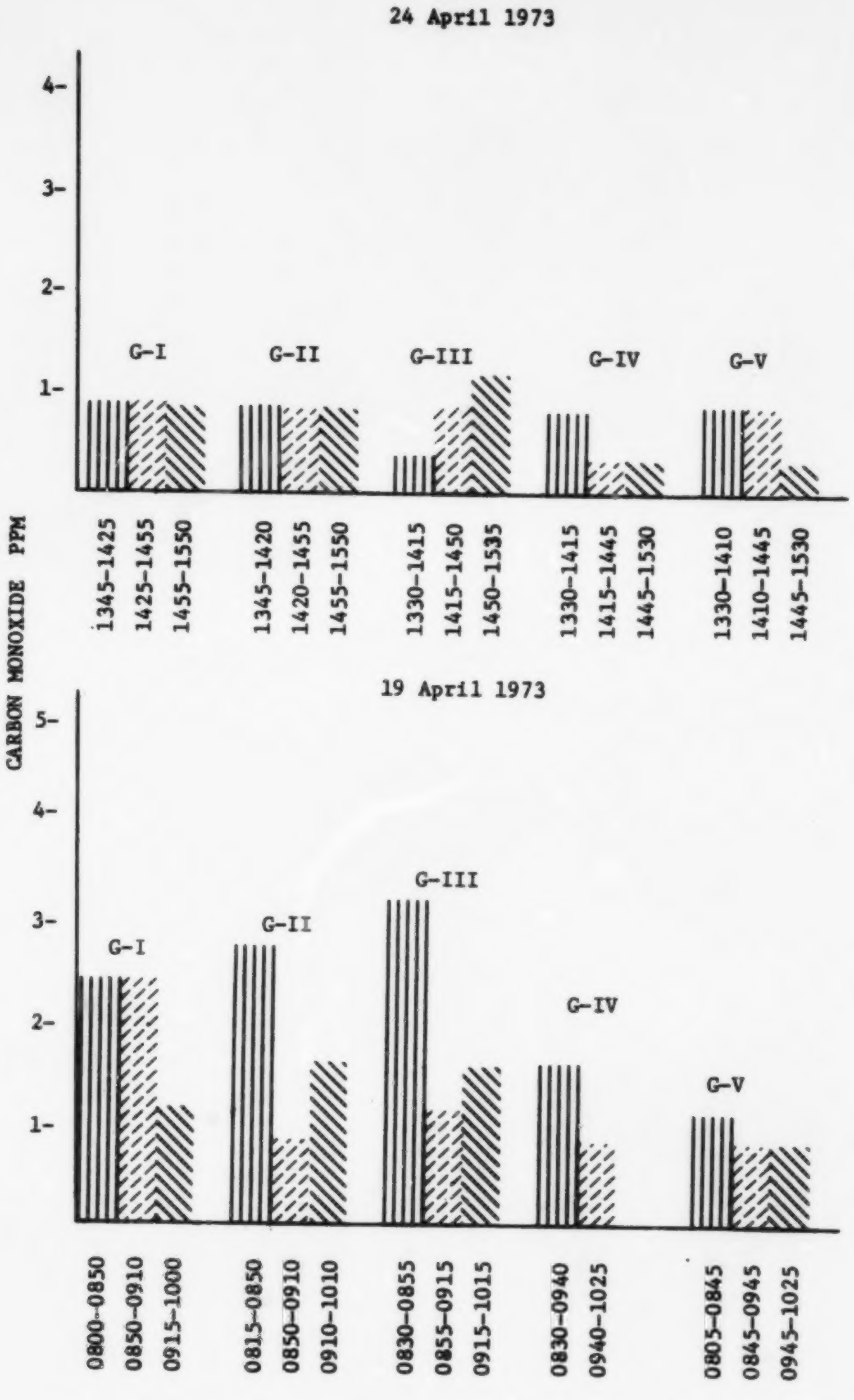


Figure 13. Grab Sample Results April 19, 24

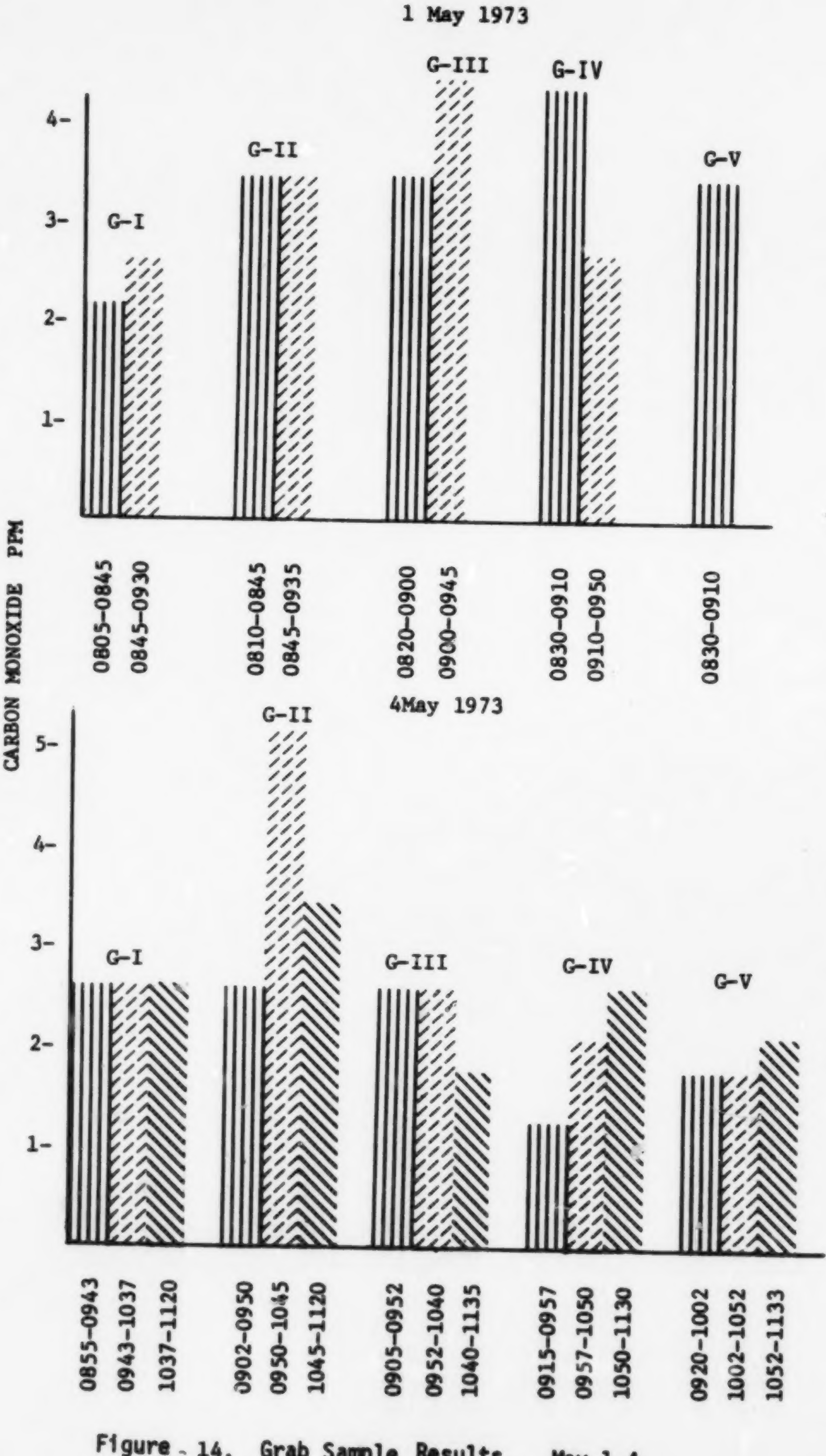


Figure 14. Grab Sample Results May 1,4

2 May 1973

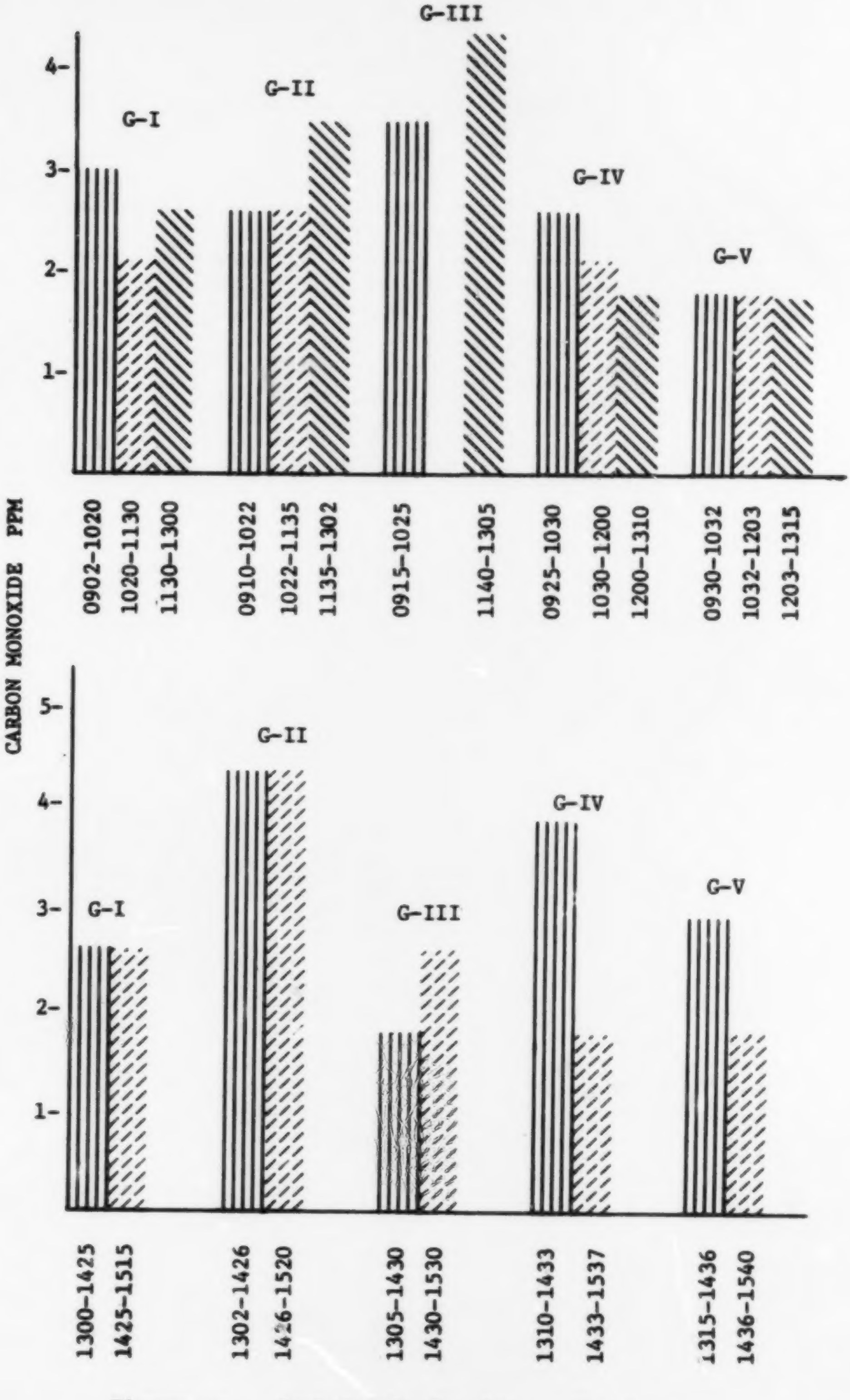


Figure 15.. Grab Sample Results May 2

Table 1. Comparison of Carbon Monoxide Measurements Using Analysis of Gas Chromatograph and Mine Safety Appliance LIRA Analyzers (data in ppm)

	GI		GII		GIII		GIV		GV	
	GC	MSA	GC	MSA	GC	MSA	GC	MSA	GC	MSA
May 2	2.6	3.0	3.5	4.0	4.3	5.3	1.8	2.0	1.8	2.0
May 4	2.6	4.0	2.6	5.2	2.6	3.5	1.2	3.0	1.8	3.0

Table 2. Wind Speed and Direction During Grab Sampling Periods

		Wind Speed	Wind Direction
17 April	0700	04	19
	0800	05	20
	0900	05	19
	1000	05	19
	1100	06	18
19 April	0800	05	18
	0900	07	19
	1000	06	22
	1100	05	18
24 April	1300	05	09
	1400	04	12
	1500	06	31
	1600	08	26
1 May	0800	04	03
	0900	03	21
	1000	03	16
2 May	0900	10	22
	1000	10	21
	1100	07	20
	1200	06	18
	1300	08	18
	1400	14	18
	1500	16	20
	1600	16	19
4 May	0900	10	21
	1000	08	21
	1100	08	26
	1200	10	33

Preliminary analyses indicate, qualitatively at least, trends in the expected directions. Higher concentrations tend to occur in the more central terminal portions of the airport (G-II, G-III and G-IV, compared to G-I and G-V) where there are generally more aircraft, and aircraft-related, ground activities. They also tend to occur near the peak time periods of aircraft activity (approximately 0900 to 1200, and 1600 to 1900).

Aircraft activity observations were made on eight different days for varying lengths of time during the daylight hours. Times for making observations were scheduled so observations would be made during all hours of the day. Aircraft observations were made according to the plan outlined in the Intensive Study Period which noted that an observer would be required for aircraft arrivals, another for aircraft departures and two more observers for at-gate activity. One additional person was required to distribute and collect grab samples when aircraft activity recording and grab sampling was being done at the same time.

Grab sampling periods did not usually coincide with the aircraft activity observations for two reasons, 1) the problem of scheduling the number of personnel required and 2) weather conditions were not acceptable. Unacceptable weather conditions include precipitation or wind velocities over 15mph.

As the intensive study period progressed it became apparent that the gate activities data did not show any real variability, consequently those observations were discontinued.

APPENDIX D

Format for Edited Processed Data Tape

The processed data tape includes a record of all data collected for the entire data collection period. There are three basic time units in the tape, i.e., 5 minute, 1-hour and 24-hour units. Because of differing data content, each time unit is recorded in a different format. The following pages describe the overall composition of the processed data tape and specify the data entered for each format. A complete 24-hour period of record has 314 sections using four different format types; the sequence of the 314 sections is shown on pages D-2 and D-3. A representation of a complete one hour unit (Section 1-13; 14-26; etc.) is outlined on page D-4. The five minute time units (12 sections per hour) uses format 1, which is shown in detail on page D-5. The thirteenth section of each hour contains all the routinely collected data for that hour. Format 2 shows the form of the hourly data summary and is shown in detail on page D-7. Format 3, shown on page D-11, is used to include the Hi-Vol particulate data which is available once every 24 hours.

The data tape and its associated users manual have been provided to the EPA project officer, Mr. D. Bruce Turner, Meteorology Division, EPA NERC, Research Triangle Park, North Carolina.

Complete 24 Hour Period; 314 Sections

			Type of Data			
Hour ending	Section(s)	Format	5 min observed	1 hour summary	24 hour Summary	Misc.
	001-012	1	X			
1	013	2		X		
	014-025	1	X			
2	026	2		X		
	027-038	1	X			
3	039	2		X		
	040-051	1	X			
4	052	2		X		
	053-064	1	X			
5	065	2		X		
	066-077	1	X			
6	078	2		X		
	079-090	1	X			
7	091	2		X		
	092-103	1	X			
8	104	2		X		
	105-116	1	X			
9	117	2		X		
	118-129	1	X			
10	130	2		X		
	131-142	1	X			
11	143	2		X		
	144-155	1	X			
12	156			X		

Hour Ending	Sections	Format	Type of data			
			5 min data	1 hour summary	24 hour summary	Non specific
	157 168	1	X			
13	169	2		X		
	170-181	1	X			
14	182	2		X		
	183-194	1	X			
15	195	2		X		
	196-207	1	X			
16	208	2		X		
	209-220	1	X			
17	221	2		X		
	222-233	1	X			
18	234	2		X		
	235-246	1	X			
19	247	2		X		
	248-259	1	X			
20	260	2		X		
	261-272	1	X			
21	273	2		X		
	274-285	1	X			
22	286	2		X		
	287-298	1	X			
23	299	2		X		
	300-311	1				
24	312	2				
24 hr summary	313	3			Hi Vol data Misc data	
Misc-non defined	314	4				

Complete 1-Hour Period; 13 Sections

1=5min

Section 01
- Date
- Time
- Format ID
- ---------
- Station ID
- Number of Channels
- Parameter Values
- ---------
- Station ID
- Number of Channels
- Parameter Values

Section 02
- Date
- Time
- Format ID
- Station ID
- Number of Channels
- Parameter Values
- Station ID
- Number of Channels
- Parameter Values
- Station ID
- Number of Channels
- Parameter Values

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Section 12
- Date
- Time
- Format ID
- ---------
- Station ID
- Number of Channels
- Parameter Values
- Station ID
- Number of Channels
- Parameter Values
- Station ID
- Number of Channels
- Parameter Values

Section 13 (hourly summary)
- ----------
- Date
- Time
- Format ID

Complete 5-Minute Period (Sections 1-12, 14-25, 27-38 ....300-311)

Fortran Format	Format 1 used for records of 5 minute intervals		
I5	DATE	72273	(Nov 1, 1972)
I5	TIME	0005	
I2	FORMAT ID	1	
I2	STATION ID	(2)	
I2	NUMBER OF CHANNELS	7	
7E12.4	PARAMETER VALUES		
	PARAMETER VALUES	(XX) $V_1, V_2, V_3, V_4, V_5, V_6, V_7$	(V=Value)
	• • • •	• • • •	
I2	STATION ID	(3)	
I2	NUMBER OF CHANNELS	12	
12E12.4	PARAMETER VALUES	$V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}, V_{11}, V_{12}$	
	• • • •		
I2	STATION ID	(6)	
I2	NUMBER OF CHANNELS	6	
6E12.6	PARAMETER VALUES	$V_1, V_2, V_3, V_4, V_5, V_6$	
	• • •		

Values recorded in format 1 correspond to the data as it was recorded by the data acquisition system after the data has been edited and converted to concentration units. Table 3 shows the sequence of which parameter were recorded at each station.

Table 3. Sequence of Parameter values in Format 1

Station ID	2	3	6
Number of Channels	7	12	6
	NO_2	NO_2	NO_2
	O_3	O_3	O_3
	Tape Sampler	Tape Sampler	Tape Sampler*
	CO	CO	CO
	CH_4	CH_4	CH_4
	THC*	THC	THC
	Tape Sampler**	Photometer	
		Wind Sigma	
		Wind Direction	
		Wind Speed	
		Temperature	
		Precipitation Event	

* THC = Total hydrocarbons

** The tape sampler from Station 6 was moved to Station 2 to obtain comparison values for different configurations of sample air intake.

Format 2 Used for Hourly Summary (Sections 13, 26, 39,..........312)

Fortran Format		Station		
I5				Date
I5				Time
I2				Format ID = 2
37E12.4				
	(1)	2	00	NO_2
	(2)	2	01	O_3
		2	02	
	(3)	2	03	CO 1 Hour
	(4)	2	04	CH_4
	(5)	2	05	THC
	(6)			NMHC
	(7)	3	00	NO_2
	(8)	3	01	O_3
	(9)	3	03	CO
	(10)	3	04	CH_4
	(11)	3	05	THC
	(12)			NMHC
	(13)	3	06	Photometer
	(14)	3	07	Wind Sigma
	(15)	3	08	Wind Direction
	(16)	3	09	Wind Speed
	(17)	3	10	Temperature
	(18)	3	11	Precipitation
	(19)	6	00	NO_2
	(20)	6	01	O_3
	(21)	6	03	CO
	(22)	6	04	CH_4
	(23)	6	05	THC
	(24)			NMHC
	(25)	CO		Station 1
	(26)	CO		Station 4
	(27)	CO		Station 5
	(28)	CO		Station 7

(29)	Stability Category
(30)	Mixing depth (EMSU) (DCA)
(31)	Indicator 1,2,3,4
(32)	Mixing depth (Radiosonde)
(33)	Indicator
(34)	Mixing depth (Thermasonde)
(35)	Aircraft activity commercial
(36)	Aircraft activity private
(37)	Aircraft activity total
( )	
( )	

* NMHC = Non Methane Hydrocarbons

The parameter values in format 2 are the average of the values from format 1 for the corresponding hour. There may be as many as 12 values averaged for each hour. When there was missing data during any hour then the hourly value is the average of as many valid data points as there were available in that hour.

Non-methane hydrocarbons are determined by subtracting the averaged methane concentration from the averaged total hydrocarbons for that hour.

Values from the paper tape sampler would not have any meaning if the values were averaged and the soiling index was not determined at the time of writing the processed data tape consequently there is no data from the tape samplers in the hourly summaries.

Precipitation event was recorded - not the amount of precipitation. A value of 0.01 in the 18th word (precipitation event) of the hourly summary indicates precipitation was recorded by the tipping bucket raingage during that hour.

Table 4 shows the units of the parameters recorded.

The method for determining the mixing depth has been described in the section titled Meteorological Data. Morning and afternoon mixing heights were obtained from the EMSU at Suitland, Maryland. The data obtained from them provided observed and forecast mixing depths for urban and rural area. The mixing depths recorded on the processed data tape are a mix of urban observed, urban forecast, rural observed, and rural forecast, in that order of preference. On the data tape mixing depth is recorded in one of two words, i.e., either urban (EMSU sounding at DCA) or rural. An indicator code is recorded following the mixing depth. The indicator is interpreted as follows:

1 = observed
2 = predicted
3 = interpolated data with more than a 24-hour interval between data points
4 = data interpolated from predicted mixing depths.

Word 30 in format 2 is urban data, word 31 is the indicator for word 30. Word 32 is rural data and word 33 is the indicator for word 32.

Table 4. Units of Recorded Parameter Values

Parameter	Units
NO_2	Micrograms m^{-3}
O_3	Micrograms m^{-3}
CO	Milligrams m^{-3}
CH_4	Micrograms m^{-3}
THC	Micrograms m^{-3}
NMHC	Micrograms m^{-3}
Photometer	Microwatts Cm^{-2} Micro amphere^{-1}
Wind Sigma	degrees
Wind Direction	degrees
Wind Speed	Meter Sec.$^{-1}$
Temperature	degrees Centigrade
Precipitation Event	0.00=no precip. 0.01=precip. occurrence
Stability Category	1 through 6 corresponding to Pasquill stability classes A thru F
Mixing Depths	Meters
Aircraft Activity	Number of takeoff and landings during that hour of record

Aircraft activity data is recorded in words 34, 35 and 36. This data is from records provided by the Federal Aviation Administration. Aircraft activity is a count of take-off or landings during that hour. Word 35 is the commercial aircraft (scheduled air carriers), word 36 includes general aviation and air taxi operations, word 37 is the total activity for that hour which may not equal the sum of the first two categories due to occasional military arrival or departure.

Format 3 Used for 24 Hour Summaries (Section 313)

Fortran Format		
I5		Date
I5		Time
I2		Format ID - 3
		Parameter
7E12.6	(1)	Station 1 Particulates
	(2)	Station 2 Particulates
	(3)	Station 3 Particulates
	(4)	Station 4 Particulates
	(5)	Station 5 Particulates
	(6)	Station 6 Particulates
	(7)	Station 7 Particulates

Particulate Concentrations are Recorded as Microgram m^{-3}.

Format 4 Used for Misc Data Records (Section 314)

Fortran Format		
I5	(1)	Date
I5	(2)	Time
I2	(3)	Format ID
I3-,N(80A1)	(4)	Data Entry Indicator (0 or the number of 80 column card images to be recorded in this record.
		Data - (when (4) above is 1)

N=Number of cards to read

APPENDIX E

BASIC NREC MODEL PROGRAM

INTRODUCTION

Program Function and Capabilities

Program AIREC is a digital computer program written in the Fortran language for use with either the CDC 6600 operating system or the UNIVAC 1108 computing system. The program has been developed for the purpose of analyzing airport emission rates and neighborhood air quality effects. Based on a general set of emission factors, the program will compute the total emissions, areal distribution of emission rates, and resulting pollutant concentrations for given time periods at specified airports.

The analytical procedures on which the computer program is based have been presented in Reference 1. The over-all procedure is quite striaghtforward and involves:

1. Totaling the airport emissions based on activity at the airport during the time period.
2. Distributing the emissions among point sources which are located according to the layout of the airport, and determining an emission rate for each point source.
3. Calculating the concentrations at specified receptor points due to the above point sources, based on either long-term or short-term specifications of the meteorological conditions.

The calculation of concentrations based on long-term specifications of meteorological conditions requires summing the contribution from each source according to the relative frequency of occurrence of all combinations of meteorological conditions. On the other hand, only a very narrow range of meteorological conditions may be considered in the calculation of short-term concentrations.

The computer program is capable of considering air carrier, general aviation, or military airports in either urban or rural localities. Aircraft are divided into twelve classes: five air-carrier classes, two general-aviation classes, four military classes, and one helicopter/STOL class. Emissions of each aircraft class are assumed to occur during a ten-mode operational cycle at various locations throughout the airport. Other airport emission sources included in the program are automobile travel within the airport, heating plants, and fuel storage areas. In addition, general emissions from the airport surroundings are considered. The airport may have up to twelve terminals, hangars, runways, taxiways, roadways, heating plants, and fuel storage areas. The airport surroundings may be divided into up to fifty subdivisions. Aircraft activity may be divided among the airport facilities according to any specified distribution. Concentrations may be calculated at up to fifty receptor points.

Report Arrangement

The main body of the report begins with a section in which the input data necessary for the solution of any case are described in detail; this includes instructions for preparing and supplying this data to the program. The next section contains a discussion of the various items of output data which can be obtained from the program. The last three sections of the main body contain a sample case illustrating the use of the program, miscellaneous operational information, and a Fortran listing of the entire program (note the cited last three sections are not included in this Appendix to the GEOMET report).

Input Data

The input data used by Program AIREC falls into three main categories: general data which is applicable to all airports and time periods, airport data which is applicable to a particular airport, and time-period data which is applicable to the particular time period being considered. A detailed description of the items in each category is given below.

All but three of the input items are read into the program using NAMELIST statements. Input data referring to a NAMELIST statement begins with a $ in the second location on a new card, immediately followed by the NAMELIST name, immediately followed by one or more blank characters. Any combination of three types of data items may then follow. The data items must be separated by commas. If more than one line is needed for the input data, the last item on each line, except the last line, must be a number followed by a comma. The first location on each line should always be left blank since it is ignored. The end of a group of data is signaled by a $ in any but the first location on a line. The form that data items may take is:

1. Variable name = constant, where the variable name may be an array element or a simple variable name. Subscripts must be integer constants.
2. Array name = set of constants separated by commas where k* constant may be used to represent k consecutive values of a constant. The number of constants must be equal to the number of elements in the array.
3. Subscripted variable = set of constants separated by commas where, again, k* constant may be used to represent k consecutive values of a constant. This results in the set of constants being placed in consecutive array elements, starting with the element designated by the subscripted variable.

If the value of ITP is 1, additional sets of time-period input data should be entered (beginning with the item COMMENT) until the value of ITP is set equal to 0. Then, if the value of IAPT is 1, the input data is repeated for a new airport beginning with the item ANAME.

---

*Table 5 identifies the pollutant classification system.

Detailed Description of Input Items

The input data for Program AIREC begins with the items in the general input data. These items which are read in the namelist NAMG, are as follows:

Fortran Symbol	Description
((AEM(I,1,K), I=1,12),K=1,8)	Mass of each pollutant (K[*]) emitted during the approach mode of aircraft in each class (I[**]), gm
((AEM(I,2,K), I=1,12),K=1,8)	Constant term in the linear variation of mass of each pollutant (K) emitted per unit distance traveled in the landing mode of aircraft in each class (I), gm per m
((AEM(I,11,K), I=1,12),K=1,8)	Linear coefficient in the variation of mass of each pollutant (K) emitted per unit distance traveled in the landing mode of aircraft in each class (I), gm per m^2
((AEM(I,3,K), I=1,12),K=1,8)	Mass per unit time of each pollutant (K) emitted during the taxi mode of aircraft in each class (I), gm per sec
((AEM(I,4,K), I=1,12),K=1,8)	Mass of each pollutant (K) emitted during the idle and shutdown mode of aircraft in each class (I), gm
((AEM(I,5,K), I=1,12),K=1,8)	Mass of each pollutant (K) emitted during the maintenance mode of aircraft in each class (I), gm
((AEM(I,6,K), I=1,12),K=1,8)	Mass of each pollutant (K) emitted during the start-up and idle mode of aircraft in each class (I), gm
((AEM(I,7,K), I=1,12),K=1,8)	Mass per unit time of each pollutant (K) emitted during the idle at runway mode of aircraft in each class (I), gm per sec
((AEM (I,8,K), I=1,12),K=1,8)	Constant term in the linear variation of mass of each pollutant (K) emitted per unit distance traveled in the take-off mode of aircraft in each class (I), gm per m

---

[*] Table 5 identifies the pollutant classification system.

[**] Table 6 identifies the aircraft classification system.

Fortran Symbol	Description
((AEM(I,12,K), I=1,12),K=1,8)	Linear coefficient in the variation of mass of each pollutant (K) emitted per unit distance traveled in the take-off mode of aircraft in each class (I), gm per m^2
((AEM(I,9,K), I=1,12),K=1,8)	Mass of each pollutant (K) emitted during the climb-out mode of aircraft in each class (I), gm
((AEM(I,10,K), I=1,12),K=1,8)	Mass of each pollutant (K) emitted during the fuel-venting mode of aircraft in each class (I), gm
((USEM(I,K), I=1,10),K=1,8)	Mass per unit time of each pollutant (K) emitted per unit area of surroundings in each category (I[*]), gm per sec m^2
(ATEM(K),K= 1,8)	Mass of each pollutant (K) emitted per unit distance traveled of an automobile, gm per m
((PPEM(I,K), I=1,8),K=1,8)	Mass of each pollutant (K) emitted per flow rate of fuel in each category (I[**]), gm per sec per fuel flow rate
(ENP(I),I=1, 12)	Average number of passengers for aircraft in each class (I)
(ELDIST(I), I=1,12)	Distance traveled in the landing mode for aircraft in each class (I), m
(TDIST(I), I=1,12)	Distance traveled in the take-off mode for aircraft in each class (I), m

The input data for the computer program continues with the items in the airport input data. The first item, as specified by a FØRMAT statement, consists of 1-12 alphanumeric characters; any combination of numbers, capital letters, punctuation, or blanks may be used.

Location	Fortran Symbol	Description
1-12	ANAME	Airport name; this may be left blank but may not be omitted

The remaining items in the airport input data, which are read in the namelist NAMA, are as follows:

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[*] Table 8 identifies the categories of surroundings.

[**] Table 9 identifies the categories of heating fuels.

Fortran Symbol	Description
IAPT	Indicator: IAPT=0 if this is the last or only airport being considered IAPT=1 if additional airports remain to be considered
IUR	Indicator: IUR=0 if the airport is in a rural area IUR=1 if the airport is in an urban area
NT	Number of terminals used to accommodate aircraft activity (a maximum of 12 is allowed)
NR	Number of runways used to accommodate aircraft activity (a maximum of 12 is allowed)
NX	Number of taxiways used to accommodate aircraft activity (a maximum of 12 is allowed)
NG	Number of hangars used to accommodate aircraft activity (a maximum of 12 is allowed)
NH	Number of roadways within the airport used to accommodate automobile traffic (a maximum of 12 is allowed)
NPP	Number of heating plants located within the airport (a maximum of 12 is allowed)
NFS	Number of fuel-storage areas located within the airport (a maximum of 12 is allowed)
NS	Number of areas into which the airport surroundings are subdivided (a maximum of 50 is allowed)
(XT(I),I=1,NT)	x-coordinate* of the center of each terminal (I), m
(YT(I),I=1,NT)	y-coordinate** of the center of each terminal (I), m
(FTT(I),I=1,NT)	Fraction of aircraft activity accommodated by each terminal (I)
(XRB(I),I=1,NR)	x-coordinate of the head of each runway (I), m
(YRB(I),I=1,NR)	y-coordinate of the head of each runway (I), m

---

* The positive x direction is assumed to be East.

** The positive y direction is assumed to be North.

Fortran Symbol	Description
(XRE(I),I=1,NR)	x-coordinate of the end of each runway (I), m
(YRE(I),I=1,NR)	y-coordinate of the end of each runway (I), m
(NRSP(I),I=1,NR)	Number of ground source points along each runway (I); a minimum of 2 and a maximum of 50* is allowed for each runway
(NRAP(I),I=1,NR)	Number of approach source points associated with each runway (I); a minimum of 2 and a maximum of 50 is allowed for each runway
(NRQP(I),I=1,NR)	Number of climb-out source points associated with each runway (I); a minimum of 2 and a maximum of 50 is allowed for each runway
ADIST	Average distance traveled in the approach mode, m
CDIST	Average distance traveled in the climb-out mode, m
(XXB(I),I=1,NX)	x-coordinate of the head of each taxiway (I), m
(YXB(I),I=1,NX)	y-coordinate of the head of each taxiway (I), m
(XXE(I),I=1,NX)	x-coordinate of the end of each taxiway (I), m
(YXE(I),I=1,NX)	y-coordinate of the end of each taxiway (I), m
(NXSP(I),I=1,NX)	Number of source points along each taxiway (I); any number is allowed
(FTX(I),I=1,NX)	Fraction of aircraft activity accommodated by each taxiway (I)
TAXIT	Average aircraft time spent in the taxi mode, sec
(XG(I),I=1,NG)	x-coordinate of the center of each hangar (I), m
(YG(I),I=1,NG)	y-coordinate of the center of each hangar (I), m
(FTG(I),I=1,NG)	Fraction of aircraft activity accommodated by each hangar (I)
(XHB(I),I=1,NH)	x-coordinate of the beginning of each roadway (I) within the airport grounds, m

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* The total number of point sources allowed for an airport is limited to 999.

Fortran Symbol	Description
(YHB(I),I=1,NH)	y-coordinate of the beginning of each roadway (I) within the airport grounds, m
(XHE(I),I=1,NH)	x-coordinate of the end of each roadway (I) within the airport grounds, m
(YHE(I),I=1,NH)	y-coordinate of the end of each roadway (I) within the airport grounds, m
(NHSP(I),I=1,NH)	Number of source points along each roadway (I) within the airport grounds; any number is allowed
AUTØT	Average distance traveled by an automobile within the airport, m
FAPP	Fraction of automobiles entering the airport per passenger
(XPP(I),I=1,NPP)	x-coordinate of the center of each airport heating plant (I), m
(YPP(I),I=1,NPP)	y-coordinate of the center of each airport heating plant (I), m
(ICPP(I),I=1,NPP)	Indicator of the type of fuel used by each airport heating plant (I)
(PPKW(I),I=1,NPP)	Fuel flow rate for each airport heating plant (I)*
(XFS(I),I=1,NFS)	x-coordinate of the center of each fuel storage area (I) located within the airport, m
(YFS(I),I=1,NFS)	y-coordinate of the center of each fuel storage area (I) located within the airport, m
((FSEM(I,K),I=1,NFS),K=1,8)	Mass per unit time of each pollutant (K) emitted by each fuel storage area (I) located within the airport, gm per sec
(XQ(I),I=1,NS)	x-coordinate of the emission point for each subdivision (I) of the airport surroundings, m
(YQ(I),I=1,NS)	y-coordinate of the emission point for each subdivision (I) of the airport surroundings, m

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* Units vary with fuel type.

Fortran Symbol	Description
(ICQ(I),I=1,NS)	Indicator of the category of each subdivision (I) of the airport surroundings
(AQ(I),I=1,NS)	Area of each subdivision (I) of the airport surroundings, sq m

The input data for the computer program concludes with the items in the time-period input data. The first item, as specified by a FØRMAT statement, consists of 1-72 alphanumeric characters; any combination of numbers, capital letters, punctuations, or blanks may be used.

Location	Fortran Symbol	Description
1-72	CØMMENT	Descriptive statement; this may be left blank but may not be omitted

All but one of the remaining items in the time-period input data are read in the namelist NAMTP. They are as follows:

Fortran Symbol	Description
ITP	Indicator: ITP=0 if this is the last or only time period to be considered ITP=1 if additional time periods are considered
IMPACT	Indicator: IMPACT=0 if pollutant concentrations are not to be calculated IMPACT=1 if concentrations are to be calculated and short-term climatological data is specified IMPACT=2 if concentrations are to be calculated and long-term climatological data is specified
IWRITE	Indicator: IWRITE=0 if optional output is not to be printed IWRITE=1 if optional output is to be printed
(IPØL(K),K=1,8)	Indicator for each pollutant (K): IPØL(K)=0 if pollutant is not to be considered IPØL(K)=1 if pollutant is to be considered
HELAT	Length of time period, hrs

Fortran Symbol	Description
(ACTVTY(I),I=1,12)	Activity* during the time period of aircraft in each class (I)
APP	Average fractional activity level of the airport heating plants during the time period
ACTS	Average fractional activity level of the airport surroundings during the time period
TIDLE	Average length of idle time at the head of a runway during the time period, sec
(FTR(I),I=1,NR)	Fraction of aircraft activity accommodated by each runway (I) during the time period

If IMPACT = 1 or 2, the following four items must be specified

NRCP	Number of receptor points to be considered; up to 50 is allowed
(XRCP(I),I=1,NRCP)	x-coordinate of each receptor point (I), m
(YRCP(I),I=1,NRCP)	y-coordinate of each receptor point (I), m
(ZRCP(I),I=1,NRCP)	z-coordinate** of each receptor point (I), m

If IMPACT = 1, the following six items must be specified

HMIX	Average mixing height of the atmosphere during the time period, m
KWS	Wind speed class*** corresponding to the average wind speed during the time period
KS	Stability class# of the atmosphere during the time period
WD	Mean direction from which wind is blowing during the time period, deg (as measured positive clockwise from the North)

---

* Activity corresponds to number of operational cycles, which is one-half the number of operations as the term is used by the FAA.

** The positive z direction is upward and z=0 at ground level.

*** Table 10 identifies the wind-speed classes.

# Table 11 identifies the atmospheric stability classes.

Fortran Symbol	Description
PW	Wind persistence during the time period (angular variation of wind direction), deg
NWD	Number of wind directions considered in the calculation procedure

If IMPACT = 2, the following two items must be specified

HMIX	Mean annual afternoon mixing height, m
IFREQ	Indicator: IFREQ=0 if relative frequency data is _not_ to be read in this set of time-period input data IFREQ=1 if relative frequency data is to be read in this set of time-period input data (The value of IFREQ must be 1 for the first set of time-period input data for which IMPACT=2)

The last item in the time-period input data is specified by a FORMAT statement; it should be entered only if IMPACT = 2 and IFREQ = 1. The item is a three-dimensional array whose elements are floating-point numbers. The array must be entered in the following manner:

Card	Location	Fortran Symbol	Description
1	11-18	FREQ(1,1,1)	Relative frequency of atmospheric conditions such that the stability class is 1, the wind direction sector* is 1, and the wind speed class is 1
1	20-27	FREQ(1,1,2)	Relative frequency of atmospheric conditions such that the stability class is 1, the wind direction sector is 1, and the wind speed class is 2

Entries in locations 29-36, 38-45, 47-54, and 56-63 of card 1 containing the relative frequencies for the remaining wind speed classes, complete the set for the first wind-direction sector of the first stability class. Cards 2-16, containing the relative frequencies for the remaining wind direction sectors, complete the entries for the first stability class. Cards 17-96 complete the entries for the remaining stability classes.

---

* Table T2 identifies the wind-direction sectors.

Table 5. POLLUTANT CLASSIFICATION SYSTEM

Index Number	Pollutant
1	Carbon Monoxide
2	Nitrogen Oxides
3	Sulphur Dioxide
4	Total Particulates
5	Lead
6	Total Hydrocarbons
7	Reactive Hydrocarbons
8	Aldehydes

Table 6. AIRCRAFT CLASSIFICATION SYSTEM

Index Number	Aircraft Class
1	Supersonic Jet Transport
2	Jumbo Jet Transport
3	Long-range Jet Transport
4	Medium-range Jet Transport
5	Turboprop Transport
6	Business Jet
7	Piston Utility
8	Military: over 400,000 lbs
9	Military: 100,000-400,000 lbs
10	Military: 10,000-100,000 lbs
11	Military: under 10,000 lbs
12	Helicopter /STOL

Table 7. CLASSIFICATION SYSTEM OF AIRCRAFT OPERATIONAL MODES

Index Number	Operational Mode
1	Approach
2	Landing
3	Taxi
4	Idle and Shutdown
5	Maintenance
6	Start-up and Idle
7	Idle at Runway
8	Take-off
9	Climb-out
10	Fuel Dumping

Table 8. SURROUNDINGS CLASSIFICATION SYSTEM

Category Number	Surroundings
1	City Center
2	Urban
3	Suburban
4	Semi-rural
5	Rural
6	Cemetery
7	Park
8	Airport

Table 9. HEATING FUEL CLASSIFICATION SYSTEM

Category Number	Heating Fuel
1	Fuel Oil
2	Natural Gas
3	LPG Butane
4	LPG Propane
5	Bituminous Coal
6	Anthracite

Table 10. WIND SPEED CLASSIFICATION SYSTEM*

Class Number	Wind Speed Range
1	0-3 mph
2	4-7 mph
3	8-12 mph
4	13-18 mph
5	19-25 mph
6	over 24 mph

*GEOMET uses observed speed.

Table 11. ATMOSPHERIC STABILITY CLASSIFICATION SYSTEM

Class Number	Description
1	Most Unstable
2	Unstable
3	Slightly Unstable
4	Neutral
5	Stable
6	Most Stable

Table 12. WIND DIRECTION CLASSIFICATION SYSTEM

Sector* Number	Wind Direction
1	N
2	NNE
3	NE
4	ENE
5	E
6	ESE
7	SE
8	SSE
9	S
10	SSW
11	SW
12	WSW
13	W
14	WNW
15	NW
16	NNW

Output Data

The output of Program AIREC consists entirely of printed data. The printed data can be divided into the following categories:

1. General input data.
2. Airport input data.
3. Time-period input data.
4. Total emissions of each aircraft class (optional).
5. Total emissions of all aircraft.
6. Total emissions of airport and surroundings.
7. Areal distribution of emission rates.
8. Pollutant concentrations at each receptor point.

The items in the first three categories have been described in the description of input data. The items in the remaining categories are described below.

The total emissions of each aircraft class during the time period, category 4, are printed if IWEITE = 1. Values of the items given for each pollutant being considered in the time period. The items are:

1. Mass of pollutant, gms, emitted during each mode of the operational cycle.
2. Total mass of pollutant, gms, emitted during entire operational cycle.
3. Mass of pollutant, gms, emitted by automobiles associated with the aircraft class.

The total emissions of all aircraft during the time period, category 5, are given for each pollutant being considered. The items are:

1. Mass of pollutant, gms, emitted during each mode of the operational cycle.
2. Total mass of pollutant, gms, emitted during the entire operational cycle.
3. Mass of pollutant, gms, emitted by automobile travel within the airport.

The total emissions of airport and surroundings during the time period, category 6, are given for each pollutant being considered. The items are:

1. Mass of pollutant, gms, emitted during all aircraft ground operations, (modes 3, 4, 5, 6, and 7).
2. Mass of pollutant, gms, emitted during all aircraft flight operations (modes 1, 2, 8, 9, and 10).
3. Mass of pollutant, gms, emitted by automobile traffic within the airport.
4. Mass of pollutant, gms, emitted by airport heating plants and fuel storage areas.
5. Mass of pollutant, gms, emitted by airport surroundings.

The areal distribution of emission rates for the time period, category 7, are given for each source point considered. The items are:

1. x-coordinate, m, of the source point.
2. y-coordinate, m, of the source point.
3. Emission rate, gms per sec, of the source point for each pollutant being considered.

The pollutant concentrations for the time period, category 8, are given for each receptor point. The items are:

1. x-coordinate, m, of the receptor point.
2. y-coordinate, m, of the receptor point.
3. z-coordinate, m, of the receptor point.
4. Concentration, gms per cu m, of each pollutant being considered due to aircraft sources.
5. Concentration, gms per cu m, of each pollutant being considered due to automobile travel within the airport, airport heating plants, and fuel storage areas.
6. Concentration, gms per cu m, of each pollutant being considered due to airport surroundings.

APPENDIX F

AIRCRAFT OPERATIONAL AND EMISSION DATA BY CLASS*

The operational and emission parameters derived for this study (and considered up-to-date as of December, 1972) are presented in the following table, with explanatory notes as follows. The symbols and abbreviations in the Table are also discussed in the following material:

Description of Operational Modes for Air Carrier Aircraft

1. Approach - Constant velocity descent along a 3° gide path to touchdown at end of runway. Engines at 30-40% power. Approach velocity varies slightly with aircraft type (see separate table).
2. Landing - Mode consists of three sub-modes:
    a. Coast at idle power while stabilizing aircraft; duration ~10 seconds. Velocity constant, or slight deceleration.
    b. Engine reversal (assume engines at 85-90% power-equivalent to climb-out mode). Duration ~10 seconds; rapid deceleration from approach velocity to high taxi speed.
    c. Coast at idle power with wheel breaking. Duration varies with taxi-way.
3. Taxi to Terminal - Constant velocity movement along taxiway with engines at idle power. Taxi velocity ~1000 fpm. (~5m/s).
4. Gate Maneuvering and Shutdown -
    a. Maneuvering at gate with engines at idle power; duration ~30 sec.
    b. Shutdown; produces instantaneous pulse of hydrocarbon emission (essentially raw fuel), but data in quantities emitted are scarce.

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* Evaluated and compiled by E.K. Bastress, IKOR, Incorporated, operating as a consultant to GEOMET, Incorporated, (Now with A. D. Little, Inc.)

5. Auxiliary Power Unit and Support Vehicle Operation -
    a. Continuous operation of APU; duration ~45 min.
    b. Intermittant operation of support vehicle power plants; assume 2 vehicles - one gasoline-powered, one diesel - operating continuously for ~45 min.
6. Engine Start-Up and Maneuvering at Gate -
    a. Start-up may produce emission of fuel, but data scarce; should be neglected.
    b. Maneuvering at idle power; duration ~100 sec. (Argonne reports 0.6 to 5.8 min.)
7. Taxi to Runway - Similar to mode 3.

8. Delay at Runway - Average value based on operational measurements for airport being considered.

9. Take-Off - Approximately constant acceleration to lift-off velocity; profile varies with aircraft type (see separate table). Engines at 100% power and emission rates constant.

10. Climb-Out - Constant velocity ascent from lift-off. Engines at 85-90% power. Ascent profile varies with aircraft type (see separate table).

Modeling Operational Modes (Air Carrier)

1. Approach - Model as line source along 3° slope intersecting downwind end of runway.

Source strength (mass/length)

$$= \frac{E_{APP}}{V_{APP}}$$

E_{APP} = Aircraft emission rate at approach (see table)
V_{APP} = Approach velocity ≈70 meters/sec for all aircraft

2. Landing - Model as follows:
    a. Coast - Constant velocity (~60 m/s) for 10 sec. Line source extending 600m from runway end with strength = $\frac{E_{IDLE}}{60 m/s}$

b. Engine reversal - Deceleration from 60 m/s to -30 m/s in 10 sec. Source is line with strength varying from $\left(\frac{E_{CO}}{60m/s}\right)$ to $\left(\frac{E_{CO}}{30m/s}\right)$.

Source length -400m.

c. Coast with braking - Deceleration from 30 m/s to 5 m/s over distance from end of engine reversal sub-mode to taxi-way. Model as line with strength varying $\frac{E_{IDLE}}{30m/s}$ to $\frac{E_{IDLE}}{5m/s}$.

3. Taxi to Terminal - Model as line source along taxi-way with strength = $\frac{E_{IDLE}}{5m/s}$.

4,5,6 Gate Operations - Model as point source in gate vicinity with following sequence of emissions for each arrival:

a. 30 sec at E_{IDLE}

b. 45 min of combined emissions of APU* and two support vehicles.

c. 100 sec at E_{IDLE}.

7. Taxi to Runway - Similar to Mode 3.

8. Delay at Runway - Average value for airport.

9. Take-Off - Model as line source from runway end with strength varying from $\frac{E_{TO}}{5m/s}$ to $\frac{E_{TO}}{V_{LO}}$ over length = S_{TO}

V_{LO} and S_{TO} are listed for each aircraft.

10. Climb-Out - Model as line source along ascent path from end of take-off run.

Source strength = $\frac{E_{CO}}{V_{CO}}$ with

ascent angle = B_{CO}.

V_{CO} and B_{CO} are listed for each aircraft.

11. Operational Modes (General Aviation) - Modes 1,2,3,7,8,9,10 same as air carrier. Modes 4,5,6 - assume no emissions.

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* E_{APU} is listed for each aircraft.

REFERENCES

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2. Platt, M. et. al., "The Potential Impact of Aircraft Emissions upon Air Quality", Report No. 1167-1, Northern Research and Engineering Corporation, Cambridge, Massachusetts, December 29, 1971.
3. Jane's All the World's Aircraft, 1971-1972, McGraw-Hill Book Company, New York, 1971 (Also earlier editions).
4. Aviation Week & Space Technology, Forecast & Inventory Issue, March 13, 1972.
5. Rote, D.M., et. al., "Monitoring and Modeling of Airport Air Pollution", SAE Paper 720611, May 1972.

Note: All data items in tables enclosed with parentheses are estimates.

Table F-1. Aircraft Emission Rate (g/sec.) and Operational Data

Class	Aircraft	Engines	APU	Emission Rates for Total Aircraft (all engines) (g/sec)																				Operational Parameters							
				CO					HC					NO_x					Part.					m/sec			m.		m/sec	sec.	
				E_I	E_{to}	E_{co}	E_{ap}	E_{apu}	E_I	E_{to}	E_{co}	E_{ap}	E_{apu}	E_I	E_{to}	E_{co}	E_{ap}	E_{apu}	E_I	E_{to}	E_{co}	E_{ap}	E_{apu}	V_{app}	V_{to}	V_{co}	l_{land}	l_{to}	C.R.	T_{land}	T_{to}
A	B747	4JT9D	AR-GTCP 660-4	21.4	6.18	5.91	16.4	1.65	15.7	1.60	1.34	1.51	.08	3.08	140	[illegible]	27.2	.09	1.11	1.60	[illegible]	1.60	[illegible]	71.9	[illegible]	[illegible]	[illegible]	3,170	[illegible]	37	36
B	DC-10-30	3CF6	ARTGCP 700-4	16.5	[illegible]	[illegible]	7.00	.05	[illegible]	.49	[illegible]	.716	.105	1.04	[illegible]	[illegible]	65.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	L-1011	3RB211		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	1,780	[illegible]	[illegible]	-	-
C1	B-707-120B	4JT3D	Ground Cart	26.9	6.2	7.71	20.0	(.37)	49.6	2.04	2.48	2.06	[illegible]	.733	74.7	[illegible]	16.6	[illegible]	.207	[illegible]	[illegible]	[illegible]	[illegible]	70.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	B-707-320B	4JT3D	Ground Cart	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	17.77	-	-
	B-720B	4JT3D	Ground Cart	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67.7	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	DC8-50	4JT3D	Ground Cart	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	DC8-61	4JT3D	Ground Cart	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	VC-10	4 Conway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C2	B-707-120	4JT3C	Ground Cart	46.6	4.55	5.06	20.7	(.37)	44.5	.401	.45	4.17	[illegible]	1.30	[illegible]	[illegible]	16.7	[illegible]	[illegible]	[illegible]	[illegible]	1.80	[illegible]	75.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	B-720	4JT3C	Ground Cart	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C3	DC8-20	4JT4A	Ground Cart	31.6	[illegible]	[illegible]	[illegible]	(.37)	[illegible]	.50	.043	1.00	[illegible]	1.07	11.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C4	CONV-880	4CJ805-3	Ground Cart	52.1	[illegible]	[illegible]	[illegible]	(.37)	[illegible]	.100	.204	1.20	[illegible]	.704	[illegible]	[illegible]	6.90	[illegible]	[illegible]	7.50	[illegible]	[illegible]	[illegible]	64.0	[illegible]	[illegible]	[illegible]	[illegible]	17.00	[illegible]	[illegible]
D	B-727-200	3JT8D	AR-GTCP 85-98	12.6	[illegible]	[illegible]	[illegible]	.50	2.05	.204	.340	[illegible]	[illegible]	1.00	74.7	[illegible]	11.6	[illegible]	[illegible]	[illegible]	[illegible]	.207	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	B-727-100	3JT8D	AR-GTCP 85-98CK	-	-	-	-	.38	-	-	-	-	.047	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E1	DC9-10	2JT8D	AR-GTCP 85-98D	5.42	1.80	2.34	4.29	.413	1.76	.107	.201	.442	[illegible]	.700	[illegible]	[illegible]	7.70	[illegible]	[illegible]	[illegible]	[illegible]	.270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	DC9-30	2JT8D	AR-GTCP 85-98D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	B-737-200	2JT8D	AR-GTCP 85-129	-	-	-	-	.378	-	-	-	-	[illegible]	-	-	-	-	[illegible]	-	-	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]	1,727	[illegible]	[illegible]	[illegible]
E2	BAC-111-200	2SPEY	GTCP 85-115	15.17	[illegible]	[illegible]	9.85	.378	16.7	0	[illegible]	1.58	[illegible]	.214	[illegible]	[illegible]	7.60	.187	[illegible]	[illegible]	[illegible]	.076	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Aerosp. SE-210 (Caravelle 3)	2AVON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	-	-
F	L-188A (Electra)	4-501-D13 T56-A15	(AR-GTCP 85-98)	4.41	1.90	1.71	1.78	(.39)	3.71	.222	[illegible]	.100	(.019)	[illegible]	16.1	11.9	[illegible]	(.168)	[illegible]	[illegible]	1.51	1.51	[illegible]	[illegible]	[illegible]	[illegible]	1,512	[illegible]	[illegible]	[illegible]	[illegible]
G	CONV-580	2501-D13	(Ground Cart)	2.21	.949	.857	.879	(.37)	1.80	.111	.101	[illegible]	[illegible]	[illegible]	7.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.785	.778	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	NAMC-YS11A-200	2 DART	(AR-GTCP 30-92)	(1.76)	[illegible]	[illegible]	(1.31)	(.122)	[illegible]	[illegible]	[illegible]	(.121)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(.101)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,113	6.14	[illegible]	[illegible]
	F-27	2 DART	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	1,219	[illegible]	[illegible]	-	-
	FH-227	2 DART	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	1,219	[illegible]	[illegible]	-	-
	Aerosp.N262	2 BASTAN	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	[illegible]	7.40	-	-
I	Beech 99	2 PT6A	(AR-GTCP 30-92)	[illegible]	(.101)	(.151)	[illegible]	(.123)	(.214)	(.084)	(.016)	(.06)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(.101)	(.151)	[illegible]	[illegible]	[illegible]	[illegible]	677	[illegible]	[illegible]	[illegible]	[illegible]
	DHC Twin Otter	2 PT6A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	457	[illegible]		-

APPENDIX G

STATISTICAL TREATMENTS

We desire to study the capability of the NREC and the modified NREC by measuring the amount of agreement between a given model's predictions and the corresponding observed values. However, agreement can be measured in many ways, and it is not clear at this time which are most appropriate. Therefore, it was decided to calculate several measures of agreement, each emphasizing some different aspect of the prediction errors, and then, as the work progresses, to examine the results to determine which measures should eventually be used in the final selection of a best model. Because standards emphasize different time periods for different pollutants, we emphasize different measures for different pollutants.

A computer program has been written to calculate the measures. The printouts from the program are included in this report (Section 2.5). Therefore, in describing the measures below, reference will be made to where they appear on the printout.

The first five measures are descriptive statistics of both the predicted and observed values. In all cases, only raw variables are used, i.e., no logarithms. In the description below, X_i, $i=1,2,...,N$ denotes the N values of a distribution.

1. Percentiles.

If a set of data is arranged in order of magnitude from lowest to highest, the set of values dividing the data into one hundred equal parts are called percentiles. Five percentiles were calculated: 50th (median), 75th, 90th, 95th, and 98th. These percentiles do not necessarily match precisely with the distribution curves of Section 2.5.2, since the calculations were done independently, with class intervals which sometimes differed.

2. Arithmetic Mean.

$\overline{X} = (1/N) \sum_{i=1}^{N} X_i$ (notation on printout is means of calculated and observed).

3. Standard Deviation.

$s = \left[1 \Big/ (N-1) \sum_{i=1}^{N} (X_i - \overline{X})^2 \right]^{1/2}$ (Standard deviation of calculated and observed).

4. Skewness.

Skewness $= \left[1 \Big/ (N-1) \sum_{i=1}^{N} (X_i - \overline{X})^3 \right] \Big/ s^3$; a measure of asymmetry, or departure from symmetry, of a distribution. Typically, air quality data are skewed to the right (positive values of skewness) indicating a trailing off or long-tail of high values. (Skewness of calculated and observed).

5. Kurtosis.

Kurtosis $= \left[1 \Big/ (N-1) \sum_{i=1}^{N} (X_i - \overline{X})^4 \right] \Big/ s^4$; a measure of the peakedness or flatness of a distribution relative to the normal distribution. For the normal distribution, kurtosis = 3; higher values indicate a more peaked distribution and lower ones a flatter distribution. Air quality data distributions are generally more peaked than the normal.

Six additional measures were calculated. These involve statistical testing of the agreement between the predicted and observed data. Before describing the measures, a brief indication of the nature of statistical tests of significance is useful. A test value is calculated from the data (e.g., correlation coefficient, Student's t, etc.). A null hypothesis is made (e.g., zero correlation, the mean of the predicted values equals the mean of the observed values, etc.). A statistical test asks how likely it would be to observe a test value as extreme or more extreme than the one actually calculated, if the null hypothesis were true. If it is fairly likely, that is if the statistical test produces a likelihood greater than some prespecified figure (e.g., 0.05), then the calculated test value is not adequate evidence that the null hypothesis is not true. It is then stated that the calculated test value is not significantly different from what would be expected by random fluctuations.

In the descriptions below, X_i denotes model predictions and Y_i the corresponding observations, and $i=1,2,\ldots,N$.

6. Correlation coefficient, r, between predicted and observed values.

Under the null hypothesis of independence between predicted and observed, $r=0$. For the range of N values most often used here, r greater than approximately 0.16 indicates significance at the 0.05 level. Another way of determining significance is to calculate the regression coefficient b in the regression equation $\hat{Y} = a+b\ X$ where X is the predicted value. b is normally distributed with a mean of zero and a standard deviation which is a function of the observations. The printout is:

Product moment of correlation =

Number of pairs of values =   with an error value return of

Intercept of regression line =

Coefficient of the linear term =

Standard error of regression coefficient =

If the ratio of the last to the next to last value exceeds +1.64 then the correlation coefficient is significantly positive at the 0.05 level.

7. *The t-test for the means of paired observations.*

Let $d_i = X_i - Y_i$, then the test value is $\underline{t} = N^{\frac{1}{2}} \bar{d} / s_d$ where $\bar{d}$ is the mean and s_d the standard deviation of the differences. The null hypothesis is that the two means are equal (i.e., $\bar{d} = 0$). Under this null hypothesis, and with the values of N used here, *t* will lie in the range -2 to +2 with 0.95 probability. If *t* is outside this range, then there is evidence that the null hypothesis is not true and that the mean of the two distributions do differ significantly at the 0.05 level of significance. For the t-test to be strictly valid, the difference must be normally distributed, departures from this assumption weaken the power of the test. The printout notation is:

The t statistic =   with   degrees of freedom. The blank spaces indicate where a number is calculated by the program and printed out.

8. *Sign test.*

As before, let $d_i = X_i - Y_i$. The test-value is the number of + or number of - signs, of d, whichever is smaller. The null hypothesis is that the predicted and observed values are equal. Under this hypothesis, positive and negative differences are equally likely and the test value is binomially distributed with an expected value of N/2. The test ignores the magnitudes of d, and therefore discards some information. However, it makes no assumptions about the distribution of the d's. A useful feature of the test is that it is applicable to the situations wherein each member of a pair, a prediction and its corresponding observed values, is hypothesized to come from the same distribution but that the distributions vary from pair to pair. This is very often the case with air quality data, where it is known that physical processes cause such variations in distributions. The computer program calculates the probability of observing a test value which deviates from N/2 by an amount as or more extreme than the calculated test value deviates. The printout is:

There are   pairs whose differences are non-zero with   plus or minus
differences, whichever is fewer. With a computed probability of
that these pairs of numbers come from the same population.

9. Spearman rank correlation coefficient, r_s

This is the correlation coefficient between the ranks of the predicted and the ranks of the observed. Under the null hypothesis of independence, r_s is very nearly normally distributed with a mean of zero and a variance of $1/(N-1)$. Thus, if $r_s/(N-2)^{1/2}$ exceeds 1.64 then this is evidence for positive correlation at the 0.05 level of significance. The difference between r and r_s is that ranks are used for r_s, which loses some information, but guards against extreme outliers which can dominate r but have much less influence on r_s. The printout is:

The computed Spearman rank correlation coefficient is
with a test of significance =   .

10. Matched pairs signed rank test.

Let $d_i = X_i - Y_i$ and let $|d_i|$ denote the absolute value of d_i. The $|d_i|$ are ranked from lowest to highest and the ranks are then assigned the sign of the corresponding d_i. The test value is the sum of the ranks assigned negative signs or the sum of ranks assigned positive signs, whichever is smaller. The null hypothesis, as before, is that the predicted and observed values are equal. Under the null hypothesis, and using a normal approximation (which is very good), the expected value of the test value is $N(N+1)/4$ and its variance is $N(N+1)\ (2N+1)/24$. This test lies somewhat between tests 7 and 8 in that it does not require normality as does the t-test, but it does not entirely discard the magnitudes of the differences, as does the sign test. The program calculates the probability of observing a test value which deviates from the expected value by an amount equal to, or more extreme than, the deviation of the calculated test value. The printout is:

Number of pairs of matched samples whose differences are non-zero =

Sum of the ranks of plus or minus differences =

Standardized normal score =   and the computed probability of obtaining as extreme a value =   .

11. Kolmogorov - Smirnov test.

The N predicted and N observed values together give 2N values of air quality. Let Z_k, $k=1,2,\ldots,2N$ denote the values. For each Z_k, two quantities are calculated:

A_k = (number of predicted values which are $\leq Z_k$)/N

B_k = (number of observed values which are $\leq Z_k$)/N

The test statistic is the maximum of the 2N values of $|A_k - B_k|$. The K-S test does not pair the values. The null hypothesis is that the two distributions are the same. Under the null hypotheses a value at least as large as $L = 1.36(2/N)^{1/2}$ is needed for significance at the 0.05 level. A test value larger than L is evidence that the two distributions are not the same. The test makes no assumptions about the form of the distributions of the predicted and observed values (e.g., they do not have to be normal). The computer program calculates the probability of observing a test value as extreme as or more extreme than the calculated test value, given that the null hypothesis is true. The printout is:

```
Kolmogorov - Smirnov statistic =           .  Probability of exceeding
Kolmogorov - Smirnov statistic =           .
```

12. <u>Histogram of errors</u>.

Also included, for information purposes, is a histogram which shows the distribution of errors (calculation minus observation). Perfect prediction would imply all errors to be zero; hence, the nearer to zero and the more peaked the distribution, the better the prediction. This printout is not included in the report, to reduce the number of pages. Example printout cases are given in Tables G-1 through G-4. These cases correspond to Figures 26 through 29 in the main report.

Table G-1

```
            CALCULATED VALUES OF CARBON MONOXIDE FROM THE NREC MODEL FCR 7-14 NOVEMBER.


                       PERCENTILE  VALUES  CF  THE  DISTRIBUTIONS
                                                                          MEANS     STANDARD    SKEWNESS    KURTOSIS
                   0.50        0.75        C.90        0.95        0.98                DEVIATION

CALCULATED         1.050       2.450       4.002       5.700       8.936       1.943      3.900       7.080      64.392

OBSERVED           2.900       4.600       6.900       9.200      15.388       3.714      4.682       6.365      58.172

ERRORS            -1.160      -0.080       1.922       3.048       5.530      -1.771      6.016


PRODUCT MOMENT OF CORRELATION          0.025789
NUMBER OF PAIRS CF VALUES  =      184  WITH AN ERROR VALUE RETURNED OF    0
INTERCEPT  OF REGRESSION LINE  =          3.653415
COEFFICIENT  OF THE LINEAR TERM  =           0.030959
STANDARD ERROR  OF REGRESSION COEFFICIENT   =          0.089957


THE T STATISTIC FROM THE PAIRED CCMPARISCN TEST IS  -3.9928   WITH 183 DEGREES OF FREEDOM.


THERE ARE 184 PAIRS WHOSE DIFFERENCES ARE NON-ZERO WITH  44 PLUS CR MINUS DIFFERENCES, WHICHEVER IS FEWER.
         WITH A COMPUTED PROBABILITY OF 0.000000 THAT THESE PAIRS CF NUMBERS CAME FROM THE SAME POPULATION.


THE COMPUTED SPEARMAN RANK CORRELATION CCEFFICIENT IS  0.081623 WITH A TEST OF SIGNIFICANCE  =   1.1048384


OUTPUT FROM THE WILCOXON MATCHED-PAIRS SIGNED-RANK TEST

                NUMBER OF PAIRS OF MATCHED SAMPLES WHOSE DIFFERENCES ARE NON-ZERO  =  184
                SUM CF THE RANKS OF PLUS CR MINUS DIFFERENCES  =        3396.50
                STANDARDIZED NORMAL SCCRE  =  -7.068315
                AND THE COMPUTED PROBABILITY OF CBTAINING AS EXTREME A VALUE  =   0.000000


KOLMCGCROV-SMIRNCV STATISTIC  =    4.170287   AND THE PROBABILITY OF EXCEEDING THE K-S STATISTIC  =   0.0
```

Table G-2

```
CALCULATED VALUES OF NON-METHANE HYDROCARBONS FROM THE NREC MODEL FOR 6-21 DEC.


                   PERCENTILE  VALUES  OF  THE  DISTRIBUTIONS
                                                                         MEANS     STANDARD    SKEWNESS    KURTOSIS
             0.50       0.75       0.90       0.95       0.98                     DEVIATION

CALCULATED   51.120     139.050    400.700    541.020    714.980        142.792    267.428      4.713      30.981

OBSERVED    353.000     669.500   1468.200   1617.600   2065.520        526.726    585.877      1.274       0.927

ERRORS     -235.000       0.135    123.920    293.100    515.116       -383.931    652.228


PRODUCT MOMENT OF CORRELATION          -0.033920
NUMBER OF PAIRS OF VALUES  =      106  WITH AN ERROR VALUE RETURNED OF    0
INTERCEPT  OF REGRESSION LINE  =        537.337402
COEFFICIENT  OF THE LINEAR TERM  =          -0.074312
STANDARD ERROR  OF REGRESSION COEFFICIENT   =          0.214700


THE T STATISTIC FROM THE PAIRED COMPARISON TEST IS  -6.0605   WITH 105 DEGREES OF FREEDOM.


THERE ARE 106 PAIRS WHOSE DIFFERENCES ARE NON-ZERO WITH  35 PLUS OR MINUS DIFFERENCES, WHICHEVER IS FEWER,
          WITH A COMPUTED PROBABILITY OF 0.000338 THAT THESE PAIRS OF NUMBERS CAME FROM THE SAME POPULATION.


THE COMPUTED SPEARMAN RANK CORRELATION COEFFICIENT IS  0.132047 WITH A TEST OF SIGNIFICANCE  =   1.3585119


OUTPUT FROM THE WILCOXON MATCHED-PAIRS SIGNED-RANK TEST

               NUMBER OF PAIRS OF MATCHED SAMPLES WHOSE DIFFERENCES ARE NON-ZERO  =  106
               SUM OF THE RANKS OF PLUS OR MINUS DIFFERENCES  =        1030.00
               STANDARDIZED NORMAL SCORE  =  -5.665521
               AND THE COMPUTED PROBABILITY OF OBTAINING AS EXTREME A VALUE  =   0.000000


KOLMOGOROV-SMIRNOV STATISTIC  =     3.227972   AND THE PROBABILITY OF EXCEEDING THE K-S STATISTIC  =   0.0
```

Table G-3

```
       CALCULATED VALUES OF NITROGEN DIOXIDE FROM THE NREC MODEL FOR 7 - 16 NOVEMBER.


                        PERCENTILE  VALUES  CF  THE  DISTRIBUTIONS
                                                                            MEANS     STANDARD    SKEWNESS    KURTOSIS
                  0.50        0.75        0.90        0.95        0.98                DEVIATION

CALCULATED        0.050       0.090       0.294       0.502       2.144        0.175     0.603       6.685       49.236

OBSERVED          0.120       0.260       0.430       0.526       0.600        0.176     0.167       1.431       2.010

ERRORS           -0.050       0.020       0.122       0.342       1.818       -0.001     0.624


PRODUCT MOMENT OF CORRELATION          0.134523
NUMBER OF PAIRS OF VALUES  =      108  WITH AN ERROR VALUE RETURNED OF    0
INTERCEPT  OF REGRESSION LINE  =          0.169857
COEFFICIENT  OF THE LINEAR TERM  =          0.037274
STANDARD ERROR  OF REGRESSION COEFFICIENT   =          0.026668


THE T STATISTIC FROM THE PAIRED CCMPARISCN TEST IS  -0.0207   WITH 107 DEGREES OF FREEDOM.


THERE ARE 101 PAIRS WHOSE DIFFERENCES ARE NCN-ZERO WITH  31 PLUS OR MINUS DIFFERENCES, WHICHEVER IS FEWER.
          WITH A COMPUTED PROBABILITY OF 0.000078 THAT THESE PAIRS CF NUMBERS CAME FROM THE SAME POPULATION.


THE COMPUTED SPEARMAN RANK CORRELATION CCEFFICIENT IS  0.103976 WITH A TEST OF SIGNIFICANCE  =   1.0763359


OUTPUT FROM THE WILCOXON MATCHED-PAIRS SIGNED-RANK TEST

              NUMBER CF PAIRS OF MATCHED SAMPLES WHOSE DIFFERENCES ARE NON-ZERO  =  101
              SUM OF THE RANKS OF PLUS OR MINUS DIFFERENCES  =          1400.00
              STANDARDIZED NORMAL SCORE  =  -3.982168
              AND THE COMPUTED PROBABILITY OF OBTAINING AS EXTREME A VALUE  =   0.000034


KOLMOGOROV-SMIRNOV STATISTIC  =    2.381448   AND THE PROBABILITY OF EXCEEDING THE K-S STATISTIC  =   0.000024
```

nued)

Table G-4

```
        CALCULATED VALUES OF SUSPENDED PARTICULATES FROM THE NREC MODEL FOR 7-16 NOV.


                     PERCENTILE  VALUES  OF  THE  DISTRIBUTIONS
                                                                        MEANS     STANDARD    SKEWNESS    KURTOSIS
                0.50       0.75       0.90       0.95       0.98                   DEVIATION

CALCULATED     26.500     46.600    126.790    174.420    227.598         51.493     63.064      2.498       6.568

OBSERVED       75.750     92.950    125.480    142.930    156.714         82.832     31.639      0.978       0.841

ERRORS        -35.750    -15.925     25.180    119.630    147.286        -31.339     72.531


PRODUCT MOMENT OF CORRELATION           -0.070823
NUMBER OF PAIRS OF VALUES  =       43  WITH AN ERROR VALUE RETURNED OF    0
INTERCEPT  OF REGRESSION LINE  =          84.662079
COEFFICIENT  OF THE LINEAR TERM  =           -0.035532
STANDARD ERROR  OF REGRESSION COEFFICIENT    =          0.078155


THE T STATISTIC FROM THE PAIRED COMPARISON TEST IS  -2.8333   WITH  42 DEGREES OF FREEDOM.


THERE ARE  43 PAIRS WHOSE DIFFERENCES ARE NON-ZERO WITH   8 PLUS OR MINUS DIFFERENCES, WHICHEVER IS FEWER.
          WITH A COMPUTED PROBABILITY OF 0.000037 THAT THESE PAIRS OF NUMBERS CAME FROM THE SAME POPULATION.


THE COMPUTED SPEARMAN RANK CORRELATION COEFFICIENT IS -0.045386 WITH A TEST OF SIGNIFICANCE  =  -0.2909112


OUTPUT FROM THE WILCOXON MATCHED-PAIRS SIGNED-RANK TEST

               NUMBER OF PAIRS OF MATCHED SAMPLES WHOSE DIFFERENCES ARE NON-ZERO  =   43
               SUM OF THE RANKS OF PLUS OR MINUS DIFFERENCES  =          180.00
               STANDARDIZED NORMAL SCORE  =  -3.537961
               AND THE COMPUTED PROBABILITY OF OBTAINING AS EXTREME A VALUE  =   0.000202


KOLMOGOROV-SMIRNOV STATISTIC  =    3.127150   AND THE PROBABILITY OF EXCEEDING THE K-S STATISTIC  =   0.0
```

APPENDIX H

INCREMENTAL EFFECTS OF SELECTED SUBMODELS ON PREDICTED CONCENTRATIONS AS COMPARED TO OBSERVATIONS

APPENDIX H

INCREMENTAL EFFECTS OF SELECTED SUBMODELS ON PREDICTED CONCENTRATIONS AS COMPARED TO OBSERVATIONS

All comparisons of NREC or modified models with observations were carried out by selecting adequate samples of the relevant pollutant observations for comparison, and by using the corresponding input data (meteorological and aircraft activity) to generate the appropriate predictions. All input data were obtained by objective techniques from standard inputs derivable from routine FAA and NOAA observations. The primary focus of attention with the dependent data is on validation of the more stringent case of one-hour observations recognizing, nevertheless, that the standards variously relate to one-hour, 8-hour, 6-9 a.m., 24-hour, and longer-term concentrations. The dependent sample of data employed in the tests consisted on a ten-day (7 through 16 November, 1972) set of observations at from three to seven stations inside the airport environs.

All comparisons of the dependent data in this appendix involve use of data from all stations combined. Examination of station-by-station comparisons was reserved for comparisons of the final model with the independent sample, which could be made sufficiently large to permit such analyses. (Section V, main text).

The comparisons of predictions with observations, which show the effects of incremental model changes on predictions for the principal modifications, are given in Table H-1. For each pollutant we compare the line which gives the statistics of the observations with the line for whichever model version we are examining. The four model cases given are: NREC* (the basic NREC model, but implemented as described in Section V); NREC*/1 (the same model but with the addition of the major peripheral highways); NREC*/2 (the same as NREC*/1 but with increased detail in the airport taxiways terminals and employees' roadways and parking areas); and finally the so-called GEOMET model with all the modifications and structural changes described in Section V.

Table H-1. Statistics of the Observations and the Predictions From Various Model Versions,** For All Stations Combined

Pollutant	Percentiles 10%	25%	50%	75%	90%	95%	98%	Mean
CO, mg/m^3 (184 single hour cases)								
Observations	0.58	1.2	2.9	4.6	6.9	9.2	15	3.7
Models:								
NREC*	0.0	0.28	1.1	2.5	4.0	5.7	8.9	1.9
NREC*/1	0.38	0.90	1.6	3.1	5.2	9.4	18.7	3.1
NREC*/2	0.22	0.90	1.7	3.8	6.2	9.5	16	3.6
GEOMET	0.53	1.34	2.4	4.3	8.5	15	32	4.4
Particulates, $\mu g/m^3$ (84 twenty-four hour cases)								
Observations	48	60	76	93	125	143	157	83
Models:								
NREC*	38	46	57	77	157	204	258	82
NREC*/1	35	58	72	105	184	259	372	75
NREC*/2	41	52	65	90	140	165	230	85
GEOMET	40	44	59	88	117	152	180	69
NO_2, mg/m^3 (108 single hour cases)								
Observations	0.03	0.05	0.12	0.26	0.43	0.53	0.60	0.18
Models:								
NREC*	0.0	0.01	0.05	0.09	0.29	0.50	2.1	0.18
NREC*/1	0.03	0.07	0.10	0.16	0.30	0.66	2.3	0.28
NREC*/2	0.02	0.04	0.08	0.17	0.43	0.66	1.8	0.37
GEOMET	0.04	0.08	0.20	0.38	1.15	2.6	11.5	0.66
NMHC, $\mu g/m^3$ (106 single hour cases)								
Observations	0.0	27	353	670	1470	1620	2070	527
Models:								
NREC*	0.0	0.0	51	139	401	541	715	143
NREC*/1	0.0	30	116	400	762	1110	2520	325
NREC*/2	24	65	150	570	1100	2200	3400	475
GEOMET	85	200	530	1461	2753	4540	6116	1145

** See text for identification of models.

We first recall that the original NREC model had been informally reported to underpredict by a factor of about ten. The second line for each pollutant (NREC*) shows how the change in implementation described in Section V has already made a significant improvement even before any changes are made in the model itself. Statistical tests applied to the paired comparisons showed the expected lack of correlation as discussed previously; however, the distributional statistics for the principal pollutants of interest (CO and particulates) generally tended to show improvement with the inclusion of more modifications. By the time we reach the GEOMET model case, the predicted CO distribution is quite close to the observed distribution, except above the 90th percentile, where the prediction tends higher. The particulate distribution has moved closer than for NREC; and the NMHC and NO_2 predicted distributions are both consistently higher than the observations.

The correspondence of the medians and means for CO and particulates is quite good, but both show the same tendency to have somewhat higher maximum values for the predictions. As indicated in earlier discussion in the main report, in a non-reactive model which is behaving properly, one would inferentially expect overprediction in the case of NMHC and NO_2, although the true situation for these pollutants is undoubtedly more complex than this. In any event, Table H-1 shows varying, sometimes extreme, degrees of overprediction for NMHC and NO_2. The various statistics for the GEOMET model may be summarized as follows: the "t" tests show good comparisons of the means for CO and particulates and the "pairs" tests are also good for these two. The other statistics still show the general lack of correlation of hour-by-hour pairs as before, although some modest degree of correlation appears in some cases.

The principal results, however, are reflected in the significant improvement over NREC in predictive capability for the non-reactive pollutants, coupled with a tendency to predict somewhat higher maximum values than the observations. This sets the stage for proceeding on to the independent data sample and the final validation tests and analysis, described in the final part of Section V.

APPENDIX J

This appendix contains the source listing of the modified (GEOMET) model. It has been added to the final report by the project officer in order to make the model generally available to the public. A user's manuel for this model does not exist as its preparation was not a requirement of this contract. It is up to the prospective user to search the program listing for required input parameters.

```
*** S O U R C E   P R O G R A M   L I S T I N G   09/17/74   ***   PAGE   1
C     GEOMET AIRPORT MODEL
C   CALCULATION OF AIRPORT EMISSIONS AND CONCENTRATIONS, WASHINGTON NATIONAL
C
      COMMON /COM1 / AEM(13,5,4),FOPPS(13,8),USEM(10,8), ATEM(8),
     $   ENP(15),PPEM(8,8),CAACTV(13,8),GAACTV(2,8,12)                         1
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)       2
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4          TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,         3
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)               00000110
C
      COMMON /COM4/NPOL,KPOL(8),AIMP(8),OIMP(8),SIMP(8),TAEM(10,8),
     1TATEM(8),NSRC,XSRC(999),YSRC(999),ZSRC(999),QSRC(999,8),NPUTE(999) 00000130   4
     2,NAIMP,NOIMP,NSRC1,NSRC2,NSRC3,NSRC4,NSRC5,NSRC6,NSRC7,NSRC8,NSRC9
     3,RUNIMP(8),TAXIMP(8),RODIMP(8),HIMP(8),DLYIMP(8),POTION(10,8),
     4  SERVEH(2,8)
C
      COMMON /COM5/XR,YR,ZR,XS,YS,ZS,RHO,DZM,DZP,ALPHA,ISECT,DX,DY,IRCP 00000160   5
C
      COMMON /COM6/ISS,ISC,HM,ICON,SIGZ,EXPZ,SIGY,EXPY,QS,WINDS,TKI   00000170   6
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,
     1  NOBTIM,NPRINT(20),JULIAN,ITIME                                         7
C
      COMMON /COM8/ NUMHIW,XHIWB(25),YHIWB(25),XHIWE(25),YHIWE(25),
     1 HIWLEN(25),CARS(25),EMCARS(10,6),NCARNO,NSPHIW(25),NCARSP(25),          8
     2  CARFRQ(24),EMCRFR(24)
C
      COMMON /A/ GY(6),GZ(6,5)
      COMMON /B/ XXRR,XXSR,XXZR,REP1,SEP1,REP2,SEP2,H,THETA,U,HL,KST,CLS       9
C
      NAMELIST /NAMG/ AEM,USEM,ATEM,ENP,ELDIST,TDIST,PPEM,NPRINT,IPOL,        10
     *    NRCP,XRCP,YRCP,ZRCP,INPUT,NYEAR,NDAY,NHOUR,MIN,EMFACT               11
```

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```
C
       NAMELIST /NAMA/ IAPT,NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ,AQ,XQ,YQ,  00000190
      1XT,YT,FTT,XHB,YHB,XHE,YHE,NHSP,AUTOT,FAPP,NRSP,RUNWAY,TAXIWA,
      2NRAP,NRQP,NXSP,TAXIT,XG,YG,FTG,XPP,YPP,PPKW,EMCARS,MCARNO,
      3ICPP,ADIST,CDIST,XFS,YFS,FSEM,VALUEQ,NROLE,NPRINT,NUMHIW,XHIWB,
      4YHIWB,XHIWE,YHIWE,CARS,INPUT,NYEAR,NDAY,NHOUR,MIN
C
       NAMELIST /NAMTP/ HELAT,ACTVTY,APP,ACTS,IPOL,IWRITE,IMPACT,TIDLE,  00000230
      1NRCP,XRCP,YRCP,ZRCP,ITF,HMIX,KWS,KS,NWD,WD,PW,IFREQ,FTR,NPRINT,
      2CARS,EMCARS,INCARD,INPUT,NYEAR,NDAY,NHOUR,MIN
C
       DIMENSION WIND(6), TKIX(8), EMFACT(15,4)
C
       DATA WIND/.67056,2.4587,4.4704,6.9291,9.6114,12.517/              00000260
       DATA TKIX/8*0.0/                                                  00000270
       DATA R180PI/57.29578/                                             00000280
       DATA R3PI2, RT2PI / 4.712389, 2.506628  /
       DATA RPI2,R2PI16,RPI16/1.5707963,.3926991,.1963495/               00010740
       DATA PI2/6.283185/                                                00010750
C
       JULDAY(I,J,K) = 3055*(J+2)/100 - (J+10)/13*2 - 91 + (1 - (I -
      $     I/4*4 + 3)/4 + (I - I/100*100 + 99)/100 - (I - I/
      $                       400*400 + 399)/400)*(J + 10)/13 + K
C      WHERE I IS A 4 DIGIT YEAR NUMBER, J IS THE MONTH & K IS THE DAY.
C
       ITAPE=5                                                           00000290
       NTAPE=6                                                           00000300
       INPUT = 10
       NROLE = 2
       NPAGE = 1
C
       NYEAR = 1974
       NDAY = 22
       NHOUR = 16
       MIN = 20
       HELAT = 1
C
       READ (ITAPE, 3) HEADER
     3 FORMAT (20A4)
```

```
      WRITE (NTAPE, 1) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR
    1 FORMAT (1H1,20A4, 9H  RUN AT ,I2,1H:,I2,I4,2X,A4,I6  //////)
C
C     READ GENERAL INPUT DATA
      READ (ITAPE,NAMG)                                                 00000340
      CALL PRGEN                                                        00000350
C
C     BEGIN AIRPORT LOOP, READ AIRPORT INPUT DATA                       00000380
C
      DO 152   I = 1,99
      DO 152   J = 1,4
  152 VALUEQ(I,J) = VALUEQ(I,J)*1.0E-06
C
      IF (NUMHIW .EQ. 0)   GO TO 158
      DO 155 I=1,NUMHIW
      DIST = SQRT((XHIWE(I) - XHIWB(I))**2 + (YHIWE(I) - YHIWB(I))**2)
155   HIWLEN(I) = DIST
C
 158  IF (MCARNO .EQ. 0)   GO TO 165
      DO 160 I=1,MCARNO
      DIST = SQRT((EMCARS(I,3) - EMCARS(I,1))**2 + (EMCARS(I,4) -
     $              EMCARS(I,2))**2)
160   EMCARS(I,6) = DIST
  165 IF (NR .EQ. 0)   GO TO 170
      DO 168   I = 1,NR
      DIST = SQRT((RUNWAY(I,4) - RUNWAY(I,2))**2 + (RUNWAY(I,5) -
     $                    RUNWAY(I,3))**2)
  168 RUNWAY(I,6) = DIST
  170 IF (NX .EQ. 0)   GO TO 175
      DO 172   I = 1,NX
      DIST = SQRT((TAXIWA(I,1,3)  - TAXIWA(I,1,1))**2 + (TAXIWA(I,1,4) -
     *                     TAXIWA(I,1,2))**2)
  172 TAXIWA(I,1,5) = DIST
  175 CONTINUE
C
  100 CONTINUE
      CALL PRAIR
      READ (ITAPE,NAMA)                                                 00000410
C
```

```
C     BEGIN TIME-PERIOD LOOP, READ TIME-PERIOD INPUT DATA
C
      READ (ITAPE,NAMTP)
      READ (ITAPE, 180) COMENT
  180 FORMAT (18A4)
C
      IF (INCARD)  200,200,210
C
  200 READ(INPUT,205,END=3000) JULIAN,ITIME,WD,WINDS,KS,HMIX,TOT
  205 FORMAT(I7,I6,F4.0,F7.0,F5.0)
C
C
  215 IF (KS .GT. 5)   KS = 5
      WINDS = AMAX1(WINDS,0.001)
      INDEX = ITIME/100 + 1
      DO 220   I = 1,10
  220 EMCARS(I,5)= EMCRFR(INDEX)
      DO 225   I = 1,25
  225 CARS(I) = CARFRQ(INDEX)
      IF (HMIX - 0.)  230,230,235
  230 HMIX = 10000.
      KS = 5
  235 ELAT = HELAT*3600.
C
C
       ACTVTY(7) = 0.329*TOT
       ACTVTY(8) = 0.304*TOT
       ACTVTY(9) = 0.083*TOT
       ACTVTY(11)= 0.069*TOT
       ACTVTY(12)= 0.119*TOT
      ACTVTY( 13) = 0.096*TOT
      DO 242 I = 1,6
  242 ACTVTY(I) = 0.
      ACTVTY(10) = 0.0
      CALL PRTMP
      NPOL=0
      DO 400 K=1,8
      IF (IPOL(K).EQ.0) GO TO 400
      NPOL=NPOL+1
      KPOL(NPOL)=K                                                      00000610 92
  400 CONTINUE                                                          00000620 93
C
C     CALCULATE THE TOTAL EMISSIONS IN THE TIME PERIOD                  00000630
      CALL TOTEM                                                        00000640 94
C
C     ASSOCIATE EMISSIONS WITH POINT SOURCES AND PRINT EMISSION RATES   00000650
      CALL AREAL                                                        00000660 95
C     SUBROUTINE AREAL FURNISHES NSRC, XSRC, YSRC, ZSRC, AND QSRC       00000670
C
C     IMPACT CALCULATION BEGINS HERE                                    00000690
C     BEGIN RECEPTOR LOOP                                               00000700
      IRCP=0                                                            00000710 96
 1000 IRCP=IRCP+1                                                       00000720 97
      XR=XRCP(IRCP)                                                     00000730 98
      YR=YRCP(IRCP)                                                     00000740 99
      ZR=ZRCP(IRCP)                                                     00000750100
C
      DO 1050 K=1,NPOL                                                  00000760101
      AIMP(K)=0.0                                                       00000770102
      DLYIMP(K) = 0.                                                            103
      RUNIMP(K) = 0.                                                            104
      TAXIMP(K) = 0.                                                            105
      RODIMP(K) = 0.                                                            106
      OIMP(K)=0.0                                                       00000780107
      HIMP(K) = 0.                                                              108
 1050 SIMP(K)=0.0                                                       00000790109
C
C     BEGIN SOURCE LOOP                                                 00000800
      ISRC=0                                                            00000810110
 1100 ISRC=ISRC+1                                                       00000820111
      XS=XSRC(ISRC)                                                     00000830112
      YS=YSRC(ISRC)                                                     00000840113
      ZS=ZSRC(ISRC)                                                     00000850114
C     ZERO CHECK                                                        00000860
      QTOT=0.0                                                          00000870115
C
C
      DO 1200 K=1,NPOL                                                  00000880116
 1200 QTOT=QTOT+QSRC(ISRC,K)                                          00000890117
      IF (QTOT.EQ.0.0) GO TO 2450                                            118
C
C     CALCULATE RELATIVE POSITIONS OF SOURCE AND RECEPTOR POINTS      00000910
C     USE RECEPTOR AS REFERENCE BECAUSE OF WIND DIRECTION CONVENTION  00010760
C
      DX=XS-XR                                                        00010770119
      DY=YS-YR                                                        00010780120
      RHO=SQRT(DX**2+DY**2)                                           00010790121
      IF (RHO .EQ. 0.)   GO TO 2450                                          122
      DZM=ZR-ZS                                                       00010810123
      DZP=ZR+ZS                                                       00010820124
      IF (DX .EQ. 0.)   GO TO 1225                                           125
      AL=ATAN2(DY,DX)                                                 00010840126
      GO TO 1250                                                             127
 1225 AL = RPI2                                                              128
      IF (DY.LT.0.0) AL=-AL                                           00010870129
C
C     REDEFINE ANGLE SO THAT NORTH=0 DEG AND CLOCKWISE IS POSITIVE    00010880
 1250 ALPHA = RPI2 - AL                                                      130
      IF (ALPHA.LT.0.0) ALPHA=ALPHA+PI2                               00010900131
C
C     CALCULATE SHORT-TERM CONCENTRATIONS                             00001290
2100  CONTINUE                                                               132
      ISS = KS                                                               133
      NWD = 1                                                                134
      HM=HMIX                                                         00001320135
      ENWD=NWD                                                        00001330136
      WDP = WD/R180PI                                                        137
C
C     CALCULATE RECEPTOR COORDINATES WITH RESPECT TO THE DOWNWIND AND 00001410
C     CROSSWIND DIRECTIONS                                            00001420
C
      THETA=R3PI2-WDP                                                 00011990138
      COSTH=COS(THETA)                                                00012000139
      SINTH=SIN(THETA)                                                00012010140
      X=-DX                                                           00012020141
      Y=-DY                                                           00012030142
      XP=X*COSTH+Y*SINTH                                              00012040143
      YP=-X*SINTH+Y*COSTH                                            00012050144
C
      IF (XP.LE.0.0) GO TO 2450                                              145
C
      CALL METEOR(XP,YP,XPM)                                         00001450146
      X = XP                                                                 147
      Y = YP                                                                 148
      XM = XPM                                                               149
C
C     BEGIN POLLUTANT LOOP                                           00001460
C
      DO 2400  K=1,NPOL                                              00001470150
      QS=QSRC(ISRC,K)                                                00001480151
      IF (QS.EQ.0.0) GO TO 2400                                      00001490152
C
      KP=KPOL(K)                                                     00001500153
      TKI=TKIX(KP)                                                   00001510154
C
C     CALCULATE CONCENTRATION DUE TO A POINT SOURCE                  00001520
C
      IF (ICON .EQ. 1 .AND. EXPZ .EQ. 0.0)  GO TO 2140                       155
      QUTERM=(QS/WINDS)*EXP(-TKI*X/WINDS)                            00011790156
      IF (ICON.EQ.3) GO TO 2110                                              157
C
      CHTRM=QUTERM*EXPZ/(RT2PI*SIGZ)                                 00011810158
      IF (ICON.EQ.1) GO TO 2120                                              159
C
      CHTRM1=CHTRM                                                   00011830160
 2110 CHTRM=QUTERM/HM                                                        161
      IF (ICON.EQ.3) GO TO 2120                                              162
C
      CHTRM2=CHTRM                                                   00011860163
      CHTRM=CHTRM1+(X-XM)*(CHTRM2-CHTRM1)/XM                         00011870164
 2120 IF (IMPACT.EQ.1) GO TO 2130                                            165
      CHI=CHTRM/(R2PI16*X)                                           00011890166
      GO TO 2150                                                             167
C
 2130 CHI=CHTRM*(EXPY/(RT2PI*SIGY))                                          168
      GO TO 2150                                                             169
 2140 CHI = 0.
      GO TO 2400
C
 2150 TERM24 = CHI
C
      IF (ISRC .GT. NSRC1)   GO TO 2160
      AIMP(K) = AIMP(K) + TERM24
      GO TO 2400
 2160 IF (ISRC .GT. NSRC2)   GO TO 2200
      DLYIMP(K) = DLYIMP(K) + TERM24
      GO TO 2400
 2200 IF (ISRC .GT. NSRC3)   GO TO 2202
      RUNIMP(K) = RUNIMP(K) + TERM24
      GO TO 2400
 2202 IF (ISRC .GT. NSRC4)   GO TO 2204
      TAXIMP(K) = TAXIMP(K) + TERM24
      GO TO 2400
 2204 IF (ISRC .GT. NSRC5)   GO TO 2206
      RODIMP(K) = RODIMP(K) + TERM24
      GO TO 2400
 2206 IF (ISRC .GT. NSRC7)   GO TO 2208
      OIMP(K) = OIMP(K) + TERM24
      GO TO 2400
 2208 IF (ISRC .GT. NSRC8)   GO TO 2210
      SIMP(K) = SIMP(K) + TERM24
      GO TO 2400
 2210 HIMP(K) = HIMP(K) + TERM24
C
 2400 CONTINUE
C
 2450 CONTINUE
      IF (ISRC.LT.NSRC) GO TO 1100
      GO TO 2950
C
2500  CONTINUE
C
C     PRINT THE CONCENTRATIONS OF EACH POLLUTANT FOR THE THREE SOURCE
C     CATEGORIES AT THE RECEPTOR POINT
2950  CALL PRCON
```

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C
      IF (IRCP.LT.NRCP) GO TO 1000                                         00001670201
 3000 IF (ITP.EQ.1) GO TO 200                                              00001680202
      IF (IAPT.EQ.1) GO TO 100                                             00001690203
C
 9000 CALL EXIT                                                                    204
      STOP                                                                         205
      END                                                                  00001710206

 87  COMMENT CARDS        27  CONTINUATION CARDS        47 NUMBERED STATEMENTS
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```
      BLOCK DATA
      COMMON /COM1 / AEM(13,5,4),FOPPS(13,8),USEM(10,3), ATEM(8),
     $    ENP(15),PPEM(8,8),CAACTV(13,8),GAACTV(2,8,12)
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4          TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      COMMON /COM8/ NUMHIW,XHIWB(25),YHIWB(25),XHIWE(25),YHIWE(25),
     1 HIWLEN(25),CARS(25),EMCARS(10,6),MCARNO,NSPHIW(25),NCARSP(25),
     2  CARFRQ(24),EMCRFR(24)
C
      COMMON /A/ GY(6),GZ(6,5)
C
      DIMENSION DATA1(150),DATA2(150)
      EQUIVALENCE (AEM(1), DATA1), (AEM(131), DATA2)
C
      DATA GY/0.4,0.205,0.2,0.13,0.098/
C
      DATA GZ/2*0.0002539,0.0383,2*2.0886,1.2812,2*0.04936,0.1393,
     A2*1.1137,0.9467,0.1154,0.1014,0.112,0.9109,0.926,0.91,0.7368,
     B0.2591,0.0856,0.5642,0.6869,0.8651,1.2969,0.2527,0.0818,
     C0.4421,0.6341,0.8155/
C
      DATA POLLUT / 'CARB','ON M','ONOX','IDE ','    ','    ',
     2     'TOTA','L HY','DROC','ARBO','NS  ','    ',
     3     'NITR','OGEN',' OXI','DES ','    ','    ',
     4     'TOTA','L PA','RTIC','ULAT','ES  ','    ',
     5     'REAC','TIVE',' HYD','ROCA','RBON','S   ',
     6      'SULP','HUR ','DIOX','IDE ','    ','    ',
     7      'LEAD','    ','    ','    ','    ',
     8      'ALDE','HYDE','S   ','    ','    ','    '  /
C
      DATA  DATA1/ 51.4, 19.5, 54.9, 46.6, 31.6, 32.1, 12.6, 8.42,15.17,          13
     14.41, 2.21, 1.76, .882,
     2            4.18, 2.53, 6.2, 4.55, 9.49, 14.7, 2.84, 1.89, 3.58,
     31.90, .949, .202, .101,
     4            5.91, 2.52, 7.71, 3.06, 9.24, 14.6, 3.36, 2.24, 3.86,
     51.71, .357, .302, .151,
     6            16.4, 7.03, 20.0, 24.7, 13.3, 21.6, 6.88, 4.59, 9.85,
     71.76, .379,  1.31, .655,
     8            1.03, .080, .370, .370, .370, .370, .300, .415, .379,
     9.300, .370,  .123, .123,
     *            13.7, 5.82, 49.6, 46.5, 32.6, 13.8, 2.65, 1.76, 16.7,
     13.73, 1.86,  .428, .214,
     2            1.49, .490, 2.34, .431, .340, .280, .294, .197, 0.,
     3.222, .111,  .028, .014,
     4            1.34, .504, 2.48, .450, .643, .294, .348, .232, .061,
     5.202, .101,  .028, .014,
     6            1.51, .718, 3.94, 4.17, 1.93, 1.23, .663, .442, 1.06,
     7.164, .082,  .121, .060,
     8            .060, .105, .002, .002, .002, .002, .019, .026, .001,
     9.019, .002,  .002, .002,
      DATA DATA2      /3.06,1.36,.721,1.25,1.37, .791,1.10, .733, .214,           14
     1.620, .310,  .479, .239,
     2            363., 204., 74.7, 60.0, 119., 55.8, 74.7, 49.8, 38.6,
     314.1, 7.03,  1.84, .920,
     4            232., 126., 48.5, 42.7, 78.4, 37.3, 49.5, 33.0, 28.9,
     511.9, 5.59, 1.66, .832,
     6            27.2, 65.5, 11.0, 11.7, 18.1, 3.98, 11.6, 7.76, 7.66,
     73.69, 1.84, .857, .428,
     8            .590, .544, .123, .123, .123, .123, .145, .168, .137,
     9.145, .123, .026, .026,
     *            1.11, .015, .227, .202, .605, .655, .139, .091, .034,
     1.806, .403, .151, .076,
     2            1.89, .238, 4.16, 3.28, 10.6, 7.56, 1.40, .932, 4.03,
     31.86, .932, .403, .202,
     4            2.01, .238, 4.28, 3.15, 10.1, 7.56, .983, .655, 2.52,
     51.51, .756, .302, .151,
     6              1.16, .166, 4.03, 1.64, 3.02, 2.52, .567, .378, .378,
     71.51, .756, .302, .151,
     8              .122, .063, .026, .026, .026, .026, .033, .035, .034,
     9.033, .026, .009, .009 /
C
      DATA FOPPS / 71.9, 67.1, 70.7, 73.8, 67.7, 61.6, 62.5, 67.1, 67.1,           15
     157.9, 57.9, 38.1, 38.1,
     2              91.4, 92.0, 82.3, 82.3, 82.3, 82.3, 82.3, 82.3, 61.0,
     361.0, 61.0, 61.0, 61.0,
     4              88.4, 88.4, 97.5, 97.5, 97.5, 97.5, 91.4, 91.4, 91.4,
     579.2, 79.2, 79.2, 79.2,
     6  2057.,1814.,1996.,1926.,2009.,1905.,1463.,1530.,1417.,
     7  1512.,1299.,661.,677.,
     8  3170.,3231.,2271.,3216.,2341.,1829.,2469.,1652.,2088.,
     9  1600.,1335.,1113.,646.,
     *              13.52, 10.52, 11.52, 11.02, 13.27, 17.85, 15.78,
     113.77, 12.52, 9.87, 10.27, 6.11, 8.51,
     2              37.0, 30.0, 30.0, 30.0, 26.0, 32.0, 35.0, 35.0, 35.0,
     330.0, 30.0, 30.0, 30.0,
     4              36.0, 35.0, 40.0, 40.0, 35.0, 29.0, 30.0, 28.0, 30.0,
     540.0, 30.0, 30.0, 30.0 /
C
C
      DATA ENP / 500.,315.,216.,207.,224.,210.,161.,80.,89.,60.,50.,                16
     *    57., 17., 2*0. /
C
      DATA EMCARS / -500.,-70.,-10.,-270.,-270.,-180.,4*0.,-860.,-840.,             17
     1    -700.,-705.,-780.,-770.,4*0.,-70.,-10.,-270.,-270.,-180.,
     2    -180.,4*0.,-840.,-700.,-705.,-780.,-770.,-845.,4*0.,10*25.,
     3    10.,5*5.,4*0.  /
C
      DATA FTT /.07,.04,.10,.08,.05,.08,.07,.10,.06,.05,.15,.15  /                  18
C
      DATA XT /-40.,30.,125.,70.,115.,100.,70.,65.,130.,10.,-65.,-40.  /            19
C
      DATA YT / -300.,-135.,-250.,-115.,-10.,100.,210.,300.,360.,390.,              20
     1    715.,825.  /
C
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      DATA RUNWAY / 30.,330.,150.,360.,180.,5*0.,120.,800.,-150.,450.,          21
     1    290.,5*0.,-800.,80.,1360.,-790.,1280.,5*0.,750.,-150.,800.,
     2    290.,450.,5*0.,530.,1360.,80.,1280.,-790.,5*0.,10*0.  /
C
      DATA FTR / .0,.0,.30,.0,.70, 5*0.,.05,.25,.0,.70, 6*0.  /               22
C
      DATA TAXIWA / -50.,125.,230.,220.,200.,-60.,200.,165.,200.,220.,          23
     1    125.,125.,108*0.,-350.,-300.,-260.,-105.,350.,780.,350.,950.,
     2    350.,-105.,-300.,-300.,108*0.,125.,230.,220.,200.,-60.,-150.,
     3    165.,290.,750.,800.,450.,120.,108*0.,-300.,-260.,-105.,350.,
     4    780.,1360.,950.,1280.,530.,30.,-790.,-800.,108*0.,120*0.,.03,
     5    .15,.15,.15,.05,.05,.12,.12,.0,.05,.12,.01   /
C
      DATA VALUEQ / 20.,20.,66.,66.,16.,16.,16.,16.,16.,16.,16.,16.,96.,        24
     1 96.,96.,96.,87.,87.,260.,173.,35.,20.,17.,9.,20.,12.,12.,12.,43.,
     2 14.,3.,3.,22.,22.,12.,14.,17.,17.,12.,12.,16.,116.,22.,43.,145.,
     3 145.,29.,29.,23.,17.,14.,12.,16.,16.,13.,13.,6.,6.,6.,6.,39*0.,
     4 2.39,6.31,1.87,52.52,6.31,6.31,3.17,3.17,3.17,3.17,3.17,3.17,
     5 6.31,12.12,5.31,12.12,6.03,7.53,23.27,8.90,4.55,2.85,2.79,2.53,
     6 2.16,2.51,1.81,1.99,26.25,3.17,1.58,1.58,3.17,3.17,3.17,2.65,
     7 3.17,3.17,2.65,3.17,3.17,14.80,3.94,7.69,28.53,9.96,11.06,6.91,
     8 4.52,2.16,2.94,1.96,2.04,2.04,2.04,2.04,2.04,2.04,2.04,2.04,39*0.
     9,2.53,52.55,2.04,52.55,52.55,52.55,5.27,5.27,5.27,5.27,2.62,2.62,
     $ 2.62,8.78,2.62,8.78,4.43,9.59,17.56,6.68,4.23,1.84,2.94,2.85,
     1 2.42,2.07,2.13,2.19,17.51,2.62,.518,.518,2.62,3.69,.518,1.93,
     2 .518,.518,.518,.518,.518,9.76,2.04,6.10,16.15,7.77,8.81,6.05,
     3 4.41,2.45,3.20,2.25,2.19,2.19,2.19,2.19,2.19,2.19,2.19,2.19,
     X  39*0.,
     4 .12,.52,.07,.52,.52,.52,.26,.26,.52,.52,10.5,10.5,.52,.32,.52,
     5.32,.35,.29,.66,.84,.60,.32,.98,.66,.37,.07,.52,.12,.52,.52,.52,
     6 .52,.52,.52,3.86,.52,.52,.52,.52,.52,.52,1.21,.56,.66,2.12,
     7 1.21,1.50,1.24,.78,1.44,.58,.37,.09,.09,.09,.09,.09,.09,.09,.09 ,
     8  39*0.  /
C
      DATA ATEM / 0.049,0.0084,0.0041,0.00019,0.0,0.00011,0.000091,             25
     I  0.00022  /
C
      DATA PPEM /0.005,0.32,0.84,0.77,4400.,440.,0.,0.,                         26
     2  0.6,0.13,0.37,0.34,1300.,13.,0.,0.,
     3  12.6,1.6,4.2,4.2,2700.,8000.,0.,0.,
     4  1.0,0.3,0.8,0.73,8130.,76760.,0.,0.,
     5  3*0.,
     6  18.8,0.01,0.012,0.012,73000.,8500.,0.,0.,
     7  8*0.,
     8  0.1,0.16,0.42,0.38,2.,0.,0.,0.                   /
C
      DATA XHB / -50.,-50.,10*0.  /
      DATA YHB / 30., 30., 10*0.  /
      DATA XHE / -370., -580., 10*0.  /
      DATA YHE / 1060., -310., 10*0.  /
      DATA AUTOT, FAPP / 1600., 1.5  /
      DATA XG / -220., -330., 10*0. /
      DATA YG / 900., -280., 10*0.  /
      DATA FTG / 0.416, 0.584, 10*0.  /
      DATA  XPP / -410., 11*0. /
      DATA  YPP / 150., 11*0. /
      DATA  ICPP / 1, 11*0  /
      DATA  PPKW / 0.316, 11*0.  /
      DATA XFS/-220.,-580.,10*0./
      DATA YFS / 1150.,-480.,10*0./
      DATA NXSP/3*5,4*10,5,4*10 /
      DATA NUMHIW,XHIWB / 13,-100.,-550.,-310.,200.,-175.,700.,2550.,
     $  3475.,1625.,-575.,-850.,-1975.,-4000.,12*0.  /
      DATA YHIWB / -2205.,-700.,1110.,1925.,2500.,3325.,3525.,1325.,
     $  -6200.,-6100.,1800.,1750.,-1575.,12*0.  /
      DATA XHIWE /-550.,-310.,200.,-175.,700.,2550.,3475.,1625.,-575.,
     $  -100.,-175.,-850.,-1975., 12*0.  /
      DATA YHIWE / -700.,1110.,1925.,2500.,3325.,3525.,1325.,-6200.,
     $  -6100.,-2205.,2500.,1800.,1750., 12*0.  /
      DATA ICQ / 12*3,4*7,4*3,8*8,8*4,8*3,8*2,4*3,4*4, 39*0  /
      DATA AQ / 4*2387500.,4*1835000.,4*2625000.,4*1957500., 4*2125000.,
     1  4*2007500.,4*1855000.,4*6875000.,24*7375000.,4*4925000.,39*0.  /
      DATA XQ / -600.,-1250.,-850.,-2200.,-1750.,-2100.,-3500.,-4250.,
     1  -2300.,-1950.,-4250.,-3750.,-1500.,-900.,-3000.,-2100.,650.,
     2  2200.,1000.,3100.,3100.,2750.,4400.,4250.,2300.,1700.,3450.,
     3  2200.,-1400.,-3400.,-1750.,-4500.,-5250.,-6250.,-7300.,-8800.,
     4  -6500.,-5750.,-8900.,-8200.,-4000.,-1000.,-5500.,-1400.,1250.,
     5  3600.,1650.,4800.,5450.,6500.,7300.,8800.,6400.,5250.,8800.,
      6  7400.,3600.,1900.,4750.,2250., 39*0.  /
        DATA YQ /-2700.,-2000.,-4250.,-3700.,-1250.,-450.,-2500.,-750.,      49
      1  260.,1100.,500.,1750.,2000.,2700.,3000.,3800.,3450.,2100.,4750.,
      2  3000.,700.,-700.,1000.,-1150.,-1700.,-2500.,-2600.,-3750.,-6240.
      3  ,-5700.,-8750.,-7700.,-3500.,-1250.,-5100.,-1700.,900.,2900.,
      4  1250.,4000.,5350.,6600.,7100.,8800.,6500.,5500.,8750.,7500.,
      5  3900.,1500.,5250.,1800.,-1250.,-3750.,-1900.,-5200.,-5400.,
      6  -6300.,-7400.,-8750., 39*0.   /
        DATA NRSP/ 5*40,5*0/                                                 50
        DATA NRAP/ 5*40,5*0/                                                 51
        DATA NRQP/5*40,5*0/                                                  52
        DATA NHSP / 2*15, 10*0 /                                             53
        DATA NSPHIW / 30,30,50,5,5,10,10,40,10,20,5,5,20,12*0  /             54
        DATA NCARSP / 10, 5*5, 4*0  /                                        55
        DATA  FSEM / 96*0.  /                                                56
C
        DATA XRCP/115.,-258.,640.,116.,-260.,328.,-208.,375.,2600.,41*0. /   57
C
        DATA YRCP/565.,1160.,-130.,-195.,215.,-925.,818.,1350.,4950.,        58
     *     41*0. /
C
        DATA ZRCP / 9*2.0, 41*0. /                                           59
C
        DATA MONTH / 'MAR.'  /                                               60
C
        DATA NPRINT / 17*0, 1,0,0 /                                          61
        DATA NT,NR,NX,NH,NPP,NFS,NS,IAPT,IUR,MCARNO,NG/                      62
     *   12,5,12,2,1,2,60,0,1,6,2 /
        DATA       APP,ACTS,IMPACT,IFREQ,IWRITE,ITP /    3.,1.3,1,0,0,        63
     *   1  /
        DATA CARFRG / 1080.,540.,400.,250.,250.,900.,4800.,8540.,7250.,      64
     *  4500.,4400.,4900.,4800.,4700.,4800.,6000.,7800.,7600.,6000.,
     *  4100.,3600.,3000.,2200.,1700. /
        DATA EMCRFR / 4*25.,2*50.,3*150.,125.,75.,2*100.,2*75.,100.,3*150.   65
     *  , 100.,75.,25.,50.,50.  /
        DATA ANAME / 'WASH','INGT','ON  ' /                                  66
C
        END                                                                  67

   30  COMMENT CARDS       136  CONTINUATION CARDS        0 NUMBERED STATEMENTS
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      SUBROUTINE PRTMP                                                  00004650  1
C     PRINT THE TIME-PERIOD INPUT DATA                                  00004670
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),            2
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAF(12),NRGP(12),NXSP(12),
     4          TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,           3
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)
C
      COMMON /COM6/ISS,ISC,HM,ICON,SIGZ,EXPZ,SIGY,EXPY,QS,WINDS,TKI                4
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,              5
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      NTAPE=6                                                           00004850  6
      DO 10   I = 9,12                                                            7
      IF (NPRINT(I) - 0)  1000,10,1000                                            8
   10 CONTINUE                                                                    9
      RETURN                                                                     10
C
 1000 WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                11
      NPAGE = NPAGE + 1                                                          12
 1100 FORMAT (1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE , I3)          13
      WRITE(6,1200) COMENT                                              00004880 14
 1200 FORMAT(/////51X,30H*** TIME-PERIOD INPUT DATA ***//  ,40X,18A4///)         15
      IF (NPRINT(9) .EQ. 0)  GO TO 2405                                          16
      WRITE(6,1300)                                                     00004910 17
 1300 FORMAT(55X,8HAIRCRAFT,4X,8HACTIVITY)                              00004920 18
      WRITE(6,1400)                                                     00004930 19
 1400 FORMAT(57X,5HCLASS,4X,11HDURING TIME)                             00004940 20
      WRITE(6,1500)                                                     00004950 21
 1500 FORMAT(68X,6HPERIOD,/// )                                         00004960 22
C
      DO 2000   I = 1,15                                                         23
      WRITE(6,1600) I,ACTVTY(I)                                         00004980 24
 1600 FORMAT(56X,I4,7X,F10.0,/)
 2000 CONTINUE                                                        00005000
      HELAT=ELAT/3600.0                                               00005010
      WRITE(6,2100) HELAT                                             00005020
 2100 FORMAT(////,10X,33HTHE LENGTH OF THE TIME PERIOD IS ,F6.2,      00005030
     *  6H HOURS  //)                                                 00005040
      WRITE(6,2200) APP                                               00005050
 2200 FORMAT(10X,83HTHE AVERAGE FRACTIONAL ACTIVITY LEVEL OF THE POWER P00005060
     1LANT DURING THE TIME PERIOD IS ,F6.2 //)                        00005070
      WRITE(6,2300) ACTS                                              00005080
 2300 FORMAT(10X,84HTHE AVERAGE FRACTIONAL ACTIVITY LEVEL OF THE SURROUN00005090
     1DINGS DURING THE TIME PERIOD IS ,F6.2  )                        00005100
C
 2405 IF (NPRINT(10) .EQ. 0)  GO TO 4025
C
      WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      WRITE(6,3000)                                                   00005280
 3000 FORMAT(/////47X,37HPOLLUTANTS CONSIDERED IN THE ANALYSIS,////)  00005290
      WRITE(6,3100)                                                   00005300
 3100 FORMAT(50X,9HPOLLUTANT,7X,9HPOLLUTANT)                          00005310
      WRITE(6,3200)                                                   00005320
 3200 FORMAT(52X,6HNUMBER,////)                                       00005330
      DO 4000 K=1,8                                                   00005340
      IF (IPOL(K) .EQ. 1)   WRITE (NTAPE,3300) K, (POLLUT(I,K), I=1,6)
 3300 FORMAT (54X, I2, 6X, 6A4 /)
 4000 CONTINUE                                                        00005380
C
 4025 CONTINUE
      IF (NPRINT(11) .EQ. 0)  GO TO 8000
      WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      ISEND =IMPACT+1                                                 00005400
      GO TO(7000,5000,6000),ISEND                                     00005410
 5000 WRITE (NTAPE, 5100)
 5100 FORMAT(/////,15X,100HPOLLUTANT CONCENTRATIONS ARE TO BE CALCULATED00005430
     1 AND SHORT TERM CLIMATOLOGICAL DATA IS SPECIFIED(BELOW),/////)  00005440
      WRITE(6,5200) HMIX                                              00005450
 5200 FORMAT(47X,21HTHE MIXING HEIGHT IS ,E10.3,7H METERS,//)         00005460
```

```
      WRITE(6,5300) WINDS
 5300 FORMAT (49X, 'THE WIND SPEED IS ', F8.3, ' METERS/SECOND.' //)
      WRITE(6,5400) KS                                                  00005490
 5400 FORMAT(50X,23HTHE STABILITY CLASS IS ,I2,//)                      00005500
      WRITE(6,5500) WD                                                  00005510
 5500 FORMAT(26X,58HTHE WIND DIRECTION (POSITIVE CLOCKWISE FROM THE NORT00005520
     1H) IS ,F6.0, 8H DEGREES  //)                                      00005530
      GO TO 8000                                                        00005600
 6000 IF (NPRINT(12) .EQ. 0)  GO TO 8000
      WRITE (NTAPE, 6100)
 6100 FORMAT(/////,15X,100HPOLLUTANT CONCENTRATIONS ARE TO BE CALCULATED00005620
     1 AND LONG TERM CLIMATOLOGICAL DATA IS SPECIFIED(BELOW) ,/////)    00005630
      WRITE(6,6200) HMIX                                                00005640
 6200 FORMAT(58X,14HMIXING HEIGHT=E12.5,2H M)                           00005650
      DO 6900 K=1,6                                                     00005660
      WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      WRITE(6,6600) K                                                   00005680
 6600 FORMAT(//////,37X,56HRELATIVE FREQUENCY OF WIND BLOWING WITH STABI00005690
     1LITY CLASS ,I2,/////)                                             00005700
      WRITE(6,6650)                                                     00005710
 6650 FORMAT(42X,5HSPEED,6X,5HSPEED,6X,5HSPEED,6X,5HSPEED,6X,5HSPEED,6X,00005720
     15HSPEED)                                                          00005730
      WRITE(6,6700)                                                     00005740
 6700 FORMAT(41X,7HCLASS 1,4X,7HCLASS 2,4X,7HCLASS 3,4X,7HCLASS 4,4X,7HC00005750
     1LASS 5,4X,7HCLASS 6,///)                                          00005760
      WRITE(6,6750)                                                     00005770
 6750 FORMAT(31X,10HSECTOR NO.,//)                                      00005780
      DO 6890 I =1,16                                                   00005790
      WRITE(6,6800) I,(FREQ(K,I,J),J=1,6)                               00005800
 6800 FORMAT(32X,I3,3X,6(1X,E10.3),/)                                   00005810
 6890 CONTINUE                                                          00005820
 6900 CONTINUE                                                          00005830
      GO TO 8000                                                        00005840
 7000 WRITE(NTAPE,1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      WRITE(6,7100)                                                     00005860
 7100 FORMAT(/////,42X,49HPOLLUTANT CONCENTRATIONS ARE NOT TO BE CALCULA00005870
     1TED)                                                              00005880
```

```
9000 CONTINUE                                                       00005890 90
     RETURN                                                         00005900 91
     END                                                            00005910 92

10  COMMENT CARDS       18  CONTINUATION CARDS       38 NUMBERED STATEMENTS
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      SUBROUTINE PRAIR                                                  00003120  1
C     PRINT THE AIRPORT INPUT DATA                                      00003130
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),            2
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4          TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,ITDLE,           3
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,
     2FREQ(6,16,6),FTR(10,2),COMENT(13),POLLUT(5,8)
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,              4
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      COMMON /COM8/ NUMHIW,XHIWB(25),YHIWB(25),XHIWE(25),YHIWE(25),                5
     1 HIWLEN(25),CARS(25),EMCARS(10,6),MCARNO,NSPHIW(25),NCARSP(25),
     2  CARFRQ(24),EMCRFR(24)
C
      NTAPE=6                                                           00003200  6
      ADIST = 900./0.052407779                                                    7
      CDIST = 900./0.12278456                                                     8
      WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                 9
      NPAGE = NPAGE + 1                                                          10
 1100 FORMAT (1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE , I3)          11
      WRITE (6,1150)                                                    00003230 12
 1150 FORMAT (///  53X,26H*** AIRPORT INPUT DATA ***  ///)              00003240 13
      WRITE(6,1200) (ANAME(I),I=1,3)                                    00003250 14
 1200 FORMAT(51X,18HNAME OF AIRPORT...,3A4,////)                        00003260 15
      IF (NPRINT(5) .EQ. 0)  GO TO 2095                                          16
      WRITE(6,1300)                                                     00003270 17
 1300 FORMAT(48X,35HAIRPORT SURROUNDINGS SPECIFICATIONS,//////)         00003280 18
C
      IF (NROLE .EQ. 2)  GO TO 2025                                              19
C
      WRITE(6,1400)                                                     00003290 20
 1400 FORMAT(32X,11HSUBDIVISION,8X,11HCATEGORY OF,6X,7HAREA OF,5X,23HLOC00003300 21
     1ATION OF SUBDIVISION)                                                 00003310
      WRITE(6,1500)                                                         00003320 22
 1500 FORMAT(35X,6HNUMBER,10X,11HSUBDIVISION,4X,11HSUBDIVISION,6X,7HX-COO00003330 23
     1ORD,4X,7HY-COORD)                                                     00003340
      WRITE(6,1600)                                                         00003350 24
 1600 FORMAT(69X,7HSQ  M   ,9X,3HM   ,8X,3HM   ,////)                       00003360 25
      DO 2000 I=1,NS                                                        00003370 26
      WRITE(6,1700) I,ICQ(I),AQ(I),XQ(I),YQ(I)                              00003380 27
 1700 FORMAT(35X,I6,12X,I6,7X,E10.3,4X,E10.3,1X,E10.3,/)                    00003390 28
 2000 CONTINUE                                                              00003400 29
      GO TO 2060                                                                     30
C
 2025 WRITE (NTAPE, 1450)                                                            31
 1450 FORMAT ( 68H SUBDIVISION  CATEGORY OF    AREA  OF      LOCATION  O             32
     1F  SUBDIVISION,11X,31HINPUT VALUES PER POLLUTANT TYPE, /68H    NUM
     2BER    SUBDIVISION   SUBDIVISION       X-COORD.        Y-COORD.,13X,
     329HGRAMS/SECOND PER SQUARE METER / 29X,38HSQ. METERS       METERS
     4       METERS, 14X,1H1,10X,1H2,10X,1H3,10X,1H4, ////)
      DO 2050  I = 1,NS                                                              33
 2050 WRITE (NTAPE,1750) I,ICQ(I),AQ(I),XQ(I),YQ(I),(VALUEQ(I,J),J=1,4)              34
 1750 FORMAT (I7,I12,9X,E10.3,6X,E10.3,5X,E10.3,6X,4E11.3, /)                        35
C
 2060 WRITE (NTAPE,1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                     36
      NPAGE = NPAGE + 1                                                              37
      WRITE (NTAPE,1800)                                                             38
 1800 FORMAT (///,41X,35HSURROUNDING ENVIRONS ROADWAY SYSTEM  ///)                   39
      WRITE (NTAPE,1805)                                                             40
 1805 FORMAT (10X,4HROAD,6X,19HROADWAY   BEGINNING,11X,16HROADWAY   ENDI             41
     1NG,12X,7HROADWAY,6X,9HNUMBER OF / 9X,6HNUMBER,5X,7HX-COORD,7X,
     2  7HY-COORD,7X,7HX-COORD,7X,7HY-COORD,10X,6HLENGTH,8X,4HCARS   /
     3  12X, 4(8X,6HMETERS), 11X,6HMETERS //)
      DO 2065  I = 1,NUMHIW                                                          42
      WRITE (NTAPE,1810) I,XHIWB(I),YHIWB(I),XHIWE(I),YHIWE(I),                      43
     *  HIWLEN(I),CARS(I)
 1810 FORMAT(1H0,9X,I3,1X,4E14.3,7X,F8.2,7X, F5.0)                                   44
 2065 CONTINUE                                                                       45
C
 2095 IF (NPRINT(6) .EQ. 0)  GO TO 3010                                              46
 2100 WRITE(NTAPE,1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                      47
```

```
      NPAGE = NPAGE + 1
      WRITE(6,2300)                                                     00003420
 2300 FORMAT(//   ,54X,23HTERMINAL SPECIFICATIONS,   //)                00003430
      WRITE(6,2400)                                                     00003440
 2400 FORMAT(40X,8HTERMINAL,6X,11HFRACTION OF,6X,20HLOCATION OF TERMINAL00003450
     1)                                                                 00003460
      WRITE(6,2500)                                                     00003470
 2500 FORMAT(41X,6HNUMBER,5X,15HTRAFFIC HANDLED,4X,7HX-COORD,6X,7HY-COOR00003480
     1D)                                                                00003490
      WRITE(6,2600)                                                     00003500
 2600 FORMAT(54X,11HBY TERMINAL,8X,3HM  ,10X,3HM  ,  //)                00003510
      DO 3000 I=1,NT                                                    00003520
      WRITE(6,2700) I,FTT(I),XT(I),YT(I)                                00003530
 2700 FORMAT(42X,I4,8X,F10.4,5X,E10.3,1X,E10.3,/)
 3000 CONTINUE                                                          00003550
 3010 IF (NPRINT(7) .EQ. 0)  GO TO 9010
      WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      WRITE(6,3300)                                                     00003570
 3300 FORMAT(//   ,52X,29HROADWAY SYSTEM SPECIFICATIONS,   //)          00003580
      WRITE(6,3400)                                                     00003590
 3400 FORMAT(35X,4HROAD,3X,9HNUMBER OF,5X,14HROAD BEGINNING,10X,11HROAD 00003600
     1ENDING)                                                           00003610
      WRITE(6,3500)                                                     00003620
 3500 FORMAT(34X,6HNUMBER,3X,6HSOURCE,6X,7HX-COORD,4X,7HY-COORD,4X,     00003630
     17HX-COORD,4X,7HY-COORD)                                           00003640
      WRITE(6,3600)                                                     00003650
 3600 FORMAT(43X,6HPOINTS,9X,1HM,10X,1HM,10X,1HM,10X,1HM  //)           00003660
      DO 3800 I=1,NH                                                    00003670
      WRITE(6,3700) I,NHSP(I),XHB(I),YHB(I),XHE(I),YHE(I)               00003680
 3700 FORMAT(36X,I2,7X,I2,6X,4(E10.3,1X),/)                             00003690
 3800 CONTINUE                                                          00003700
      WRITE(6,3900) AUTOT                                               00003710
 3900 FORMAT(//  ,10X,52HTHE AVERAGE AUTOMOBILE TRAVEL WITHIN THE AIRPOR00003720
     1T IS ,E10.3,7H METERS,//)                                         00003730
      WRITE(6,4000) FAPP                                                00003740
 4000 FORMAT(10X,66HTHE FRACTION OF AUTOMOBILES ENTERING THE AIRPORT PER00003750
     1 PASSENGER IS ,E10.3)                                             00003760
      WRITE(6,7300)                                                     00004330
 7300 FORMAT(//   ,52X,28HHEATING PLANT SPECIFICATIONS,   //)
      WRITE(6,7400)
 7400 FORMAT(30X,5HPLANT,7X,25HLOCATION OF HEATING PLANT,3X,
     14HFUEL,3X,16HFUEL FLOW RATE *)
      WRITE(6,7500)
 7500 FORMAT(30X,6HNUMBER,7X,7HX-COORD,7X,7HY-COORD,
     14X,8HCATEGORY)
      WRITE(6,7600)
 7600 FORMAT(44X,3HM  ,13X,3HM  ,  //)
      WRITE(6,7700) (I,XPP(I),YPP(I),ICPP(I),PPKW(I),I=1,NPP)
 7700 FORMAT(32X,I2,4X,2E13.3,6X,I2,4X,E13.3,/)
      WRITE(6,7800)
 7800 FORMAT(/    ,10X,27H* UNITS DEPEND ON FUEL TYPE)
      WRITE(6,8000)
 8000 FORMAT(//   ,52X,27HFUEL STORAGE SPECIFICATIONS,///  )
      WRITE(6,8100)
 8100 FORMAT (60X,48HMASS OF POLLUTANT EMITTED PER UNIT TIME, GMS/SEC  /
     117X,24HLOCATION OF STORAGE AREA)
      WRITE(6,8200)
 8200 FORMAT(9X,4HAREA,8X,7HX-COORD,3X,7HY-COORD,
     139X,9HPOLLUTANT)
      WRITE(6,8300)
 8300 FORMAT(8X,6HNUMBER,10X,1HM,9X,1HM,11X,1H1,
     19X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9X,1H8,////)
      DO 9000 I=1,NFS
      WRITE(6,8400) I,XFS(I),YFS(I),(FSEM(I,K),K=1,8)
 8400 FORMAT(11X,I2,4X,2E11.3,1X,3E10.3,/)
 9000 CONTINUE
C
      WRITE (NTAPE,1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      WRITE (NTAPE,8405)
 8405 FORMAT (/// 42X, 33HAIRPORT EMPLOYEES' ROADWAY SYSTEM  ///)
      WRITE (NTAPE,1805)
      DO 9005 I =1,MCARNO
      WRITE (NTAPE,1810) I,(EMCARS(I,J),J=1,4),EMCARS(I,6),EMCARS(I,5)
 9005 CONTINUE
C
 9010 IF (NPRINT(8) .EQ. 0)   RETURN
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      WRITE (NTAPE, 1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE              113
      NPAGE = NPAGE + 1                                                        114
      WRITE(6,4300)                                                    00003780115
 4300 FORMAT(//   ,53X,28HRUNWAY SYSTEM SPECIFICATIONS,    /)          00003790116
      WRITE(6,4400)                                                    00003800117
 4400 FORMAT(2X,'RUNWAY  MAGNETIC  PERCENT ACTIVITY  NUMBER OF SOURCE PO       118
     1INTS     RUNWAY BEGINNING         RUNWAY ENDING         RUNWAY' /
     22X,'NUMBER  HEADING     SOUTH     NORTH   GROUND  APPROACH  CLIMB
     3  X-COORD    Y-COORD    X-COORD    Y-COORD        LENGTH' / 57X,
     4 'OUT      METERS     METERS     METERS     METERS        METERS'/)
C
      DO 5000   I = 1,NR                                                       119
      WRITE (6,4700) I,RUNWAY(I,1),FTR(I,1),FTR(I,2), NRSP(I), NRAP(I),        120
     *   NRQP(I),   (RUNWAY(I,K), K = 2,6)
 4700 FORMAT(1H0,3X,I2,6X,F4.0,5X,F5.3,4X,F5.3, I8,I9,I8,        4X,           121
     *    4(E10.3,1X), F12.1)
 5000 CONTINUE                                                                 122
      WRITE(6,5100) ADIST                                              00003930123
 5100 FORMAT(/   ,10X,54HTHE AVERAGE DISTANCE TRAVELED IN THE APPROACH M00003940124
     1ODE IS ,F9.2,7H METERS, /)                                       00003950
      WRITE(6,5200) CDIST                                              00003960125
 5200 FORMAT(10X,55HTHE AVERAGE DISTANCE TRAVELED IN THE CLIMB-OUT MODE 00003970126
     1IS ,F9.2,7H METERS)                                              00003980
      WRITE(6,5300)                                                    00004000127
 5300 FORMAT(//   ,52X,29HTAXIWAY SYSTEM SPECIFICATIONS,   //)         00004010128
      WRITE (6, 5400)                                                          129
 5400 FORMAT(2X,'TAXIWAY  NUMBER OF    FRACTION OF       TAXIWAY   BEGIN       130
     1NING',11X,'TAXIWAY   ENDING',12X,'TAXIWAY' /2X,'NUMBER    SOURCE
     2      ACTIVITY',9X,'X-COORD',7X,'Y-COORD',7X,'X-COORD',7X,'Y-COORD'
     3,10X,'LENGTH' / 12X,'POINTS',6X,'BY TAXIWAY', 4(8X,'METERS'), 11X,
     4 'METERS' / )
C
      DO 5800   I = 1,NX                                                       131
      WRITE (6,5700) I,NXSP(I),TAXIWA(I,1,6), (TAXIWA(I,1,K), K = 1,5)         132
 5700 FORMAT(1H0,3X,I2,I12,   8X,F5.3,5X, 4(4X,E10.3), 7X, F9.2)               133
 5800 CONTINUE                                                                 134
      RETURN                                                           00004630135
      END                                                              00004640136

  15  COMMENT CARDS         43  CONTINUATION CARDS        60 NUMBERED STATEMENTS
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```
      SUBROUTINE TOTEM                                                  00005920  1
C     CALCULATION OF TOTAL EMISSIONS IN THE TIME PERIOD                 00005930
C
      COMMON /COM1 / AEM(13,5,4),FOPPS(13,8),USEM(10,8), ATEM(8),                 2
     $   ENP(15),PPEM(8,8),CAACTV(13,8),GAACTV(2,8,12)
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),           3
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4         TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,          4
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,  00006030
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)
C
      COMMON /COM4/NPOL,KPOL(8),AIMP(8),OIMP(8),SIMP(8),TAEM(10,8),     00006050  5
     1TATEM(8),NSRC,XSRC(999),YSRC(999),ZSRC(999),QSRC(999,8),NPUTE(999)
     2,NAIMP,NOIMP,NSRC1,NSRC2,NSRC3,NSRC4,NSRC5,NSRC6,NSRC7,NSRC8,NSRC9
     3,RUNIMP(8),TAXIMP(8),RODIMP(8),HIMP(8),DLYIMP(8),POTION(10,8),
     4  SERVEH(2,8)
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,             6
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      DIMENSION TAEMC(15,10,4),TAEC(15,4),TAGE(8),TAFE(8),TAE(8),TSEM(8)          7
     *    , TFSEM(8),TATEMC(15,4),TPPEM(8),SERVEM(8),SERVIC(15,2,4)
      DATA SERVEM / 0.0566650, 0.0053600, 6*0.  /                                 8
C
      AVERAG(A,B) = (8.*(A+B))/(3.*A*A + 10.*A*B + 3.*B*B)                        9
C
      NTAPE = 6                                                                   10
      SLOPEA = 900./0.052335956                                                   11
C
C     AIRCRAFT EMISSIONS                                                00006100
      DO 160   K = 1,NPOL                                                         12
      KP=KPOL(K)                                                        00006120 13
C
```

```
      DO 5   I = 1,2
    5 SERVEH(I,K) = 0.
C
C
      DO 150  J = 1,10
      TAEM(J,K) = 0.
      POTION(J,K) = 0.
      DO 150   I = 1,13
      GO TO (10,20,30,40,50,60,70,80,90,100), J
C
   10 TAEMC(I,1,K) = AEM(I,4,KP)/FOPPS(I,1)*SLOPEA
      GO TO 140
C
   20 X = AEM(I,3,KP)*200.*AVERAG(60.,30.)
      IF(FOPPS(I,4) .GT. 1000.) GO TO 22
      TAEMC(I,2,K) = X + AEM(I,1,KP)*10.
      GO TO 140
   22 DIST = (FOPPS(I,4) - 1000.)/4.
      X = X + AEM(I,1,KP)*DIST*AVERAG(30.,17.5)
      TAEMC(I,2,K) = X+AEM(I,1,KP)*DIST*AVERAG(17.5,5.)+AEM(I,1,KP)*10.
      GO TO 140
C
   30 X = AEM(I,1,KP)/5.
      SUM = 0.
      DO 32  KK = 1,1
      DO 32  II = 1,12
      IF (TAXIWA(II,KK,6) .LE. 0.)  GO TO 32
      SUM = SUM + X*TAXIWA(II,KK,5)
   32 CONTINUE
      TAEMC(I,3,K) = SUM
      GO TO 140
C
   40 IF (I .GT. 13)   GO TO 140
      TAEMC(I,4,K) = AEM(I,1,KP)*30.
      GO TO 140
C
   50 IF (I .GT. 13)   GO TO 140
      TAEMC(I,5,K) = AEM(I,5,KP)*1800.
      SERVIC(I,1,K) = SERVEM(KP)*2700.
      GO TO 140
C
   60 IF (I .GT. 13)   GO TO 140
      TAEMC(I,6,K) = AEM(I,1,KP)*100.
      GO TO 140
C
   70 TAEMC(I,7,K) = TAEMC(I,3,K)
      GO TO 140
C
   80 IF (I .GT. 13)   GO TO 140
      TAEMC(I,8,K) = AEM(I,1,KP)*60.
      GO TO 140
C
   90 SUM = 0.
      DIST = FOPPS(I,5)/10.
      A = 5.
      DELTA = (FOPPS(I,2) - 5.)/5.
      DO 92  II = 1,5
      B = A + DELTA
      SUM = SUM + AEM(I,2,KP)*DIST*AVERAG(A,B)
      A = B
   92 CONTINUE
      TAEMC(I,9,K) = SUM
      GO TO 140
C
  100 TAEMC(I,10,K) = AEM(I,3,KP)/FOPPS(I,6)*900.
C
  140 TAEMC(I,J,K) = TAEMC(I,J,K)*ACTVTY(I)
  150 TAEM(J,K) = TAEM(J,K) + TAEMC(I,J,K)
C
      DO 155   I = 1,13
      IF (I .GT. 13)   GO TO 155
      SERVIC(I,1,K) = SERVIC(I,1,K)*ACTVTY(I)
      SERVEH(I,K) = SERVEH(1,K) + SERVIC(I,1,K)
  155 CONTINUE
  160 CONTINUE
C
      DO 350 K=1,NPOL
C
```

```
      SUM = TAEM(4,K) + TAEM(5,K) + TAEM(6,K) + SERVEH(1,K)
      IF (SUM)  170,170,165
  165 POTION(1,K) = TAEM(4,K)/SUM
      POTION(2,K) = TAEM(5,K)/SUM
      POTION(3,K) = SERVEH(1,K)/SUM
      POTION(4,K) = TAEM(6,K)/SUM
  170 SUM = TAEM(3,K) + TAEM(7,K)
      IF (SUM)  180,180,175
  175 POTION(5,K) = TAEM(3,K)/SUM
      POTION(6,K) = 1.0 - POTION(5,K)
C
  180 DO 200   I = 1,13
      TAEC(I,K)=0.0                                                     00006250
      DO 200 J=1,10                                                     00006260
  200 TAEC(I,K)=TAEC(I,K)+TAEMC(I,J,K)                                  00006270
      TAGE(K)=0.0                                                       00006280
C
      TAFE(K)=0.0                                                       00006290
      DO 300 J=1,10                                                     00006300
      IF (J .LT. 2 .OR. J .GT. 8) GO TO 250
      TAGE(K)=TAGE(K)+TAEM(J,K)                                         00006320
      GO TO 300                                                         00006330
  250 TAFE(K)=TAFE(K)+TAEM(J,K)                                         00006340
  300 CONTINUE                                                          00006350
C
      TAE(K)=TAGE(K)+TAFE(K)                                            00006360
  350 CONTINUE                                                          00006370
C
C     AUTO EMISSIONS                                                    00006380
      DO 500 K=1,NPOL                                                   00006390
      KP=KPOL(K)                                                        00006400
      TATEM(K)=0.0                                                      00006410
C
      DO 500   I = 1,13
      TATEMC(I,K)=FAPP*ENP(I)*ACTVTY(I)*AUTOT*ATEM(KP)                  00006430
  500 TATEM(K)=TATEM(K)+TATEMC(I,K)                                     00006440
C
C     HEATING PLANT EMISSIONS                                           00006450
      DO 600 K=1,NPOL                                                   00006460
      KP=KPOL(K)                                                    00006470107
      TPPEM(K)=0.0                                                  00006480108
      IF (NPP .EQ. 0)   GO TO 600                                           109
      DO 550 I=1,NPP                                                00006490110
      IC=ICPP(I)                                                    00006500111
  550 TPPEM(K)=TPPEM(K)+PPKW(I)*PPEM(IC,KP)                         00006510112
  600 TPPEM(K)=APP*ELAT*TPPEM(K)                                            113
C
C     FUEL STORAGE EMISSIONS                                        00006530
  605 DO 625 K=1,NPOL                                               00006540114
      KP=KPOL(K)                                                    00006550115
      TFSEM(K)=0.0                                                  00006560116
      IF (NFS .EQ. 0)   GO TO 625                                           117
      DO 620   I = 1,NFS                                                    118
  620 TFSEM(K) = TFSEM(K) + ELAT*FSEM(I,KP)                                 119
  625 CONTINUE                                                              120
C
C     EMISSIONS OF AIRPORT SURROUNDINGS                             00006590
C
  630 IF (NROLE .EQ. 1)   GO TO 725                                         121
C
      DO 640  K=1,NPOL                                                      122
  640 TSEM(K) = 0.0                                                         123
C
      IF (NS .EQ. 0)   GO TO 850                                            124
      SUM = ACTS*ELAT                                                       125
      DO 650 IS=1,NS                                                00006630126
      DO 648   K = 1,NPOL                                                   127
      KP = KPOL(K)                                                          128
  648 TSEM(K) = SUM*AQ(IS)*VALUEQ(IS,KP) + TSEM(K)                          129
  650 CONTINUE                                                              130
      GO TO 850                                                             131
C
  725 DO 800  K=1,NPOL                                                      132
      KP=KPOL(K)                                                    00006700133
      TSEM(K)=0.0                                                   00006710134
C
      IF (NS .EQ. 0)   GO TO 800                                            135
C
```

```
      DO 750 I=1,NS                                                     00006720136
      IC=ICQ(I)                                                         00006730137
  750 TSEM(K)=TSEM(K)+AQ(I)*USEM(IC,KP)                                 00006740138
  800 TSEM(K)=ACTS*ELAT*TSEM(K)                                         00006750139
C
  850 IF (NPRINT(13) .EQ. 0)   GO TO 1900                                      140
C
C     PRINT THE TOTAL EMISSION TABLES                                   00006760
C
  900 WRITE(NTAPE, 950) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                141
  950 FORMAT(1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE ,I3 ///       142
    1 53X,25H*** AIRPORT EMISSIONS ***)
      NPAGE = NPAGE + 1                                                        143
C
      DO 1800 I = 1,13                                                         144
      IF (ACTVTY(I) .LE. 0.)  GO TO 1800                                       145
      IF(I.GT.1) WRITE(6,1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE         146
      NPAGE = NPAGE + 1                                                        147
 1000 FORMAT (1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE , I3)        148
      WRITE (6,1100) I                                                  00006830149
 1100 FORMAT (//   28X,28HEMISSIONS OF AIRCRAFT CLASS ,I2,20H IN TIME PE00006840150
    1RIOD, GMS  /)                                                      00006850
      WRITE (6, 1400)  (K, K = 1,10)                                           151
 1400 FORMAT(10H POLLUTANT,44X,17HMODE OF OPERATION,// 2X, 8I14 / 2X,          152
    1 2I14, 11X,5HTOTAL,6X,11HAUTO TRAVEL  ///)
C
      DO 1700 K=1,NPOL                                                  00006930153
      WRITE(6,1500) KPOL(K),(TAEMC(I,J,K),J=1,10),TAEC(I,K),TATEMC(I,K) 00006940154
 1500 FORMAT (I5,3X,8E14.4 // 8X,4E14.4 ///)                                   155
 1700 CONTINUE                                                          00006960156
 1800 CONTINUE                                                          00006970157
C
 1900 IF (NPRINT(14) .EQ. 0)  GO TO 2800                                       158
C
 2000 WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE              159
      NPAGE = NPAGE + 1                                                        160
      WRITE (6,2100)                                                    00006990161
 2100 FORMAT (///  48X,48HTOTAL AIRCRAFT EMISSIONS IN THE TIME PERIOD, G00007000162
    1MS///)                                                             00007010
```

```
      WRITE (6, 1400)  (K, K=1,10)                                      163
C
      DO 2700 K=1,NPOL                                          00007050164
      WRITE(6,1500) KPOL(K),(TAEM(J,K),J=1,10),TAE(K),TATEM(K)  00007060165
 2700 CONTINUE                                                  00007070166
C
 2800 IF (NPRINT(15) .EQ. 0)  RETURN                                    167
C
      WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE       168
      NPAGE = NPAGE + 1                                                 169
      WRITE (6,3100)                                            00007090170
 3100 FORMAT (/////40X,63HTOTAL EMISSIONS OF AIRPORT AND SURROUNDINGS IN00007100171
     1 TIME PERIOD, GMS///)                                     00007110
      WRITE (6,3200)                                            00007120172
 3200 FORMAT (10X,9HPOLLUTANT,13X,18HAIRCRAFT EMISSIONS,17X,30HNON-AIRCR    173
     1AFT AIRPORT EMISSIONS,13X,7HAIRPORT, / 108X,12HSURROUNDINGS, //
     2 28X,6HGROUND,14X,6HFLIGHT,17X,4HAUTO, / 26X,10HOPERATIONS, 10X,
     3 10HOPERATIONS,14X,6HTRAVEL,11X,5HOTHER ///)
C
      DO 3700 K=1,NPOL                                          00007220174
      TOTHER=TPPEM(K)+TFSEM(K)                                  00007230175
      WRITE(6,3600) KPOL(K),TAGE(K),TAFE(K),TATEM(K),TOTHER,TSEM(K)   00007240176
 3600 FORMAT(13X,I2,10X,E11.5,9X,E11.5,11X,E11.5,6X,E11.5,14X,E11.5,/)      177
 3700 CONTINUE                                                  00007260178
      RETURN                                                    00007270179
      END                                                       00007280180

 58  COMMENT CARDS         22  CONTINUATION CARDS        57 NUMBERED STATEMENTS
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      SUBROUTINE AREAL                                                  00007290   1
C
C     CALCULATION OF EMISSION RATES ASSOCIATED WITH POINT SOURCES       00007300
C
      COMMON /COM1 / AEM(13,5,4),FOPPS(13,8),USEM(10,8), ATEM(8),                  2
     $   ENP(15),PPEM(8,8),CAACTV(13,8),GAACTV(2,8,12)
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),            3
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAFP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4         TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,           4
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,  00007400
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)                     00007410
C
      COMMON /COM4/NPOL,KPOL(8),AIMP(8),OIMP(8),SIMP(8),TAEM(10,8),     00007420   5
     1TATEM(8),NSRC,XSRC(999),YSRC(999),ZSRC(999),QSRC(999,8),NPUTE(999)
     2,NAIMP,NOIMP,NSRC1,NSRC2,NSRC3,NSRC4,NSRC5,NSRC6,NSRC7,NSRC8,NSRC9
     3,RUNIMP(8),TAXIMP(8),RODIMP(8),HIMP(8),DLYIMP(8),POTION(10,8),
     4  SERVEH(2,8)
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,   00007441   6
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      COMMON /COM8/ NUMHIW,XHIWB(25),YHIWB(25),XHIWE(25),YHIWE(25),     00007443   7
     1 HIWLEN(25),CARS(25),EMCARS(10,6),MCARNO,NSPHIW(25),NCARSP(25),
     2  CARFRQ(24),EMCRFR(24)
C                                                                              >
      NTAPE = 6                                                         00007451   8
      ISRC=0                                                            00007460   9
      SIN3DG = 0.052335956                                                        10
      COS3DG = 0.99862953                                                         11
      TAN3DG = 0.052407779                                                        12
      SIN7DG = 0.12186934                                                         13
      TAN7DG = 0.12278456                                                         14
      SIN5DG = 0.087155743                                                        15
      COS5DG = 0.996194698
      TAN5DG = 0.087438664
      SN10DG = 0.173648177
      TN10DG = 0.176326981
      ADIST = 900./TAN3DG
      SLOPEA = 900./SIN3DG
      CDIST = 900./TN7DG
      SLOPEC = 900./SN7DG
      NAIMP = 0                                                         00007461
      NOIMP = 0                                                         00007462
      NSRC1 = 0                                                         00007463
      NSRC2 = 0                                                         00007464
      NSRC3 = 0                                                         00007465
      NSRC4 = 0                                                         00007466
      NSRC5 = 0                                                         00007467
      NSRC6 = 0                                                         00007468
      NSRC7 = 0                                                         00007469
      NSRC8 = 0                                                         00007469
      NSRC9 = 0
C
      IF (NT .EQ. 0)  GO TO 105                                         00007469
C                                                                              C
C     TERMINAL EMISSION SOURCES                                         00007470
      DO 100 I=1,NT                                                     00007480
      ISRC=ISRC+1                                                       00007490
      XSRC(ISRC)=XT(I)                                                  00007500
      YSRC(ISRC)=YT(I)                                                  00007510
      ZSRC(ISRC)=4.0                                                    00007520
      NPUTE(ISRC) = 1
      FT = FTT(I)/ELAT
      DO 100 K=1,NPOL                                                   00007540
  100 QSRC(ISRC,K) = FT*(TAEM(4,K) + TAEM(5,K) + TAEM(6,K) +SERVEH(1,K))
C
      NSRC1=ISRC                                                        00007560
      NAIMP = NSRC1                                                     00007561
C                                                                              C
C     RUNWAY (OR EXTENSION THEREOF) EMISSION SOURCES                    00007570
C
105   IF (NR .EQ. 0)   GO TO 1015                                       00007591
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```
      IGREAS = 2                                                        00007592
      IF (WD .GT. 90. .AND. WD .LE. 270.)   IGREAS = 1                  00007593
C
C   COMPUTION OF THE SOURCE STRENGTH FOR DELAY AT BEGINNING OF RUNWAY.
C
      DO 108    I = 1,4
      IF (FTR(I,IGREAS))  108,108,106
  106 ISRC = ISRC + 1
      IF (ISRC .GT. 999)   GO TO 1010
      XSRC(ISRC) = RUNWAY(I,2)
      YSRC(ISRC) = RUNWAY(I,3)
      ZSRC(ISRC) = 4.0
      NPUTE(ISRC) = 1
      FR = FTR(I,IGREAS)/(SLOPEA*ELAT)
      DO 107    K = 1,NPOL
  107 QSRC(ISRC,K) = TAEM(8,K)*FR
  108 CONTINUE
      NSRC2 = ISRC
      NAIMP = NSRC2
C
      DO 1000 I=1,NR                                                    00007600
      IF (FTR(I,IGREAS))  1000,1000,110                                 00007601
  110 RL = RUNWAY(I,6)
      DXR = RUNWAY(I,4) - RUNWAY(I,2)
      DYR = RUNWAY(I,5) - RUNWAY(I,3)
      FR = FTR(I,IGREAS)/(SLOPEA*ELAT)
C
C     COMPUTATION OF THE SOURCE STRENGTH FOR THE APPROACH MODE.
      ISRC = ISRC + 1
      IF(ISRC.GT.999) GO TO 1010
      DXA = DXR/RL*ADIST
      DYA = DYR/RL*ADIST
      XSRC(ISRC) = RUNWAY(I,2) - DXA
      YSRC(ISRC) = RUNWAY(I,3) - DYA
      ZSRC(ISRC) = 800.
      NPUTE(ISRC) = 1
      DO 112 K=1,NPOL
112   QSRC(ISRC,K) = TAEM(1,K)*FR
      DIST = ADIST - 7000.
      XPNT = NRAP(I)/4
      CALL POINTS(ISRC,DXA,DYA,DIST,ADIST,XPNT)
C
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      DXA = DXR/RL*7000.
      DYA = DYR/RL*7000.
      XSRC(ISRC) = RUNWAY(I,2) - DXA
      YSRC(ISRC) = RUNWAY(I,3) - DYA
      ZSRC(ISRC) = 500.
      NPUTE(ISRC) = 1
      DO 114 K=1,NPOL
  114 QSRC(ISRC,K) = TAEM(1,K)*FR
      DIST = 4000.
      XPNT = NRAP(I)/4
      CALL POINTS(ISRC,DXA,DYA,DIST,7000.,XPNT)
C
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      DXA = DXR/RL*3000.
      DYA = DYR/RL*3000.
      XSRC(ISRC) = RUNWAY(I,2) - DXA
      YSRC(ISRC) = RUNWAY(I,3) - DYA
      ZSRC(ISRC) = 300.
      NPUTE(ISRC) = 1
      DO 116 K=1,NPOL
  116 QSRC(ISRC,K) = TAEM(1,K)*FR
      DIST = 2000.
      XPNT = NRAP(I)/4
      CALL POINTS(ISRC,DXA,DYA,DIST,3000.,XPNT)
C
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      DXA = DXR/RL*1000.
      DYA = DYR/RL*1000.
      XSRC(ISRC) = RUNWAY(I,2) - DXA
      YSRC(ISRC) = RUNWAY(I,3) - DYA
      ZSRC(ISRC) = 100.
      NPUTE(ISRC) = 1
      DO 118 K=1,NPOL
118   QSRC(ISRC,K) = TAEM(1,K)*FR
      DIST = 1000.
      XPNT = NRAP(I)/4
      CALL POINTS(ISRC,DXA,DYA,DIST,1000.,XPNT)
C
C     COMPUTATION OF THE SOURCE STRENGTH FOR LANDING ON THE RUNWAY
      FR = FTR(I,IGREAS)/(RUNWAY(I,6)*ELAT)
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      XSRC(ISRC) = RUNWAY(I,2)
      YSRC(ISRC) = RUNWAY(I,3)
      ZSRC(ISRC) = 4.0
      NPUTE(ISRC) = 1
      DO 120 K=1,NPOL
120   QSRC(ISRC,K) = TAEM(2,K)*FR
      DIST = RUNWAY(I,6)
      XPNT = NRSP(I)
      CALL POINTS(ISRC,DXR,DYR,DIST,DIST,XPNT)
C
C     COMPUTATION OF THE SOURCE STRENGTH FOR TAKE-OFF ON THE RUNWAY.
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      XSRC(ISRC) = RUNWAY(I,2)
      YSRC(ISRC) = RUNWAY(I,3)
      ZSRC(ISRC) = 4.0
      NPUTE(ISRC) = 1
      DO 122 K=1,NPOL
122   QSRC(ISRC,K) = TAEM(9,K)*FR
      DIST = RUNWAY(I,6)
      XPNT = NRSP(I)
      CALL POINTS(ISRC,DXR,DYR,DIST,DIST,XPNT)
C
C     COMPUTATION OF THE SOURCE STRENGTH FOR CLIMB-OUT MODE.
      FR = FTR(I,IGREAS)/(SLOPEC*ELAT)
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      DXC = DXR/RL*1000.
      DYC = DYR/RL*1000.
      XSRC(ISRC) = RUNWAY(I,4) + DXC
      YSRC(ISRC) = RUNWAY(I,5) + DYC
      ZSRC(ISRC) = 150.
      NPUTE(ISRC) = 1
      DO 124 K=1,NPOL
  124 QSRC(ISRC,K) = TAEM(10,K)*FR
      DIST = 1000.
      XPNT = 10.
      CALL POINTS(ISRC,-DXC,-DYC,DIST,1000.,XPNT)
C
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      DXC = DXR/RL*3000.
      DYC = DYR/RL*3000.
      XSRC(ISRC) = RUNWAY(I,4) + DXC
      YSRC(ISRC) = RUNWAY(I,5) + DYC
      ZSRC(ISRC) = 400.
      NPUTE(ISRC) = 1
      DO 126 K=1,NPOL
  126 QSRC(ISRC,K) = TAEM(10,K)*FR
      DIST = 2000.
      XPNT =NRQP(I)
      CALL POINTS(ISRC,-DXC,-DYC,DIST,3000.,XPNT)
C
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1010
      DXC = DXR/RL*CDIST
      DYC = DYR/RL*CDIST
      XSRC(ISRC) = RUNWAY(I,4) + DXC
      YSRC(ISRC) = RUNWAY(I,5) + DYC
      ZSRC(ISRC) = 800.
      NPUTE(ISRC) = 1
      DO 128 K=1,NPOL
  128 QSRC(ISRC,K) = TAEM(10,K)*FR
      DIST = CDIST - 3000.
       XPNT = 10.
      CALL POINTS(ISRC,-DXC,-DYC,DIST,CDIST,XPNT)
C
 1000 CONTINUE
```

```
C
      NSRC3 = ISRC
      NAIMP = NSRC3
 1010 IF (ISRC .GT. 999)   NSRC3 = 1000
C
 1015 IF (NX .EQ. 0)   GO TO 1250
C
C     TAXIWAY EMISSION SOURCES
      THL = 0.
      DO 1150   I = 1,NX
 1150 THL = THL + TAXIWA(I,1,5)
C
      DO 1200 I=1,NX
      IF (TAXIWA(I,1,6)) 1200,1200,1025
1025  FX = TAXIWA(I,1,6)/(THL*ELAT)
      DX = TAXIWA(I,1,3) - TAXIWA(I,1,1)
      DY = TAXIWA(I,1,4) - TAXIWA(I,1,2)
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 1250
      XSRC(ISRC) = TAXIWA(I,1,1)
      YSRC(ISRC) = TAXIWA(I,1,2)
      ZSRC(ISRC) = 4.
      NPUTE(ISRC) = 1
      DO 1050   K = 1,NPOL
 1050 QSRC(ISRC,K) = FX*(TAEM(3,K) + TAEM(7,K))
      DIST = TAXIWA(I,1,5)
      XPNT = NXSP(I)
      CALL POINTS(ISRC,DX,DY,DIST,DIST,XPNT)
C
 1200 CONTINUE
C
 1250 NSRC4 = ISRC
      NAIMP = NSRC4
C
 1400 CONTINUE
C
1405  IF (NH.EQ.0) GO TO 2300
C
C     AIRPORT ROADWAY EMISSION SOURCES
```

```
      THL=0.0
C
      FH = 1./(ELAT•AUTOT)
      DO 2200 I=1•NH
      ISRC = ISRC + 1
      IF (ISRC.GT.999) GO TO 2300
      XSRC(ISRC) = XHB(I)
      YSRC(ISRC) = YHB(I)
      ZSRC(ISRC)=0.5
      NPUTE(ISRC) = 1
      DX = XHE(I) - XHB(I)
      DY = YHE(I) - YHB(I)
C
      DO 2150 K=1•NPOL
 2150 QSRC(ISRC•K)=FH•TATEM(K)
      DIST = SQRT(DX•DX + DY•DY)
      XPNT = NHSP(I)
      CALL POINTS(ISRC•DX•DY•DIST•DIST•XPNT)
C
 2200 CONTINUE
C
 2300 IF (MCARNO .EQ. 0)   GO TO 2400
C     AIRPORT EMPLOYEE"S ROADWAY EMISSION SOURCES.
C
      DO 2305   K = 1•NPOL
 2305 TATEM(K) = 0.
C
      THL = 0.
      DO 2320   I = 1•MCARNO
      THL = THL + EMCARS(I•6)
      FI = EMCARS(I•5) • EMCARS(I•6)
C
      DO 2315   K = 1•NPOL
      KP = KPOL(K)
 2315 TATEM(K) = TATEM(K) + FI•ATEM(KP)
 2320 CONTINUE
C
      FH = 1./(ELAT•THL)
      DO 2360   I = 1•MCARNO
      ISRC = ISRC + 1                                                 244
      IF (ISRC .GT. 999)   GO TO 2400                                 245
      XSRC(ISRC) = EMCARS(I,1)                                        246
      YSRC(ISRC) = EMCARS(I,2)                                        247
      ZSRC(ISRC) = 0.5                                                248
      NPUTE(ISRC) = 1                                                 249
      DX = EMCARS(I,3) - EMCARS(I,1)                                  250
      DY = EMCARS(I,4) - EMCARS(I,2)                                  251
C
      DO 2350   K = 1,NPOL                                            252
 2350 QSRC(ISRC,K) = FH*TATEM(K)                                      253
      DIST = EMCARS(I,6)                                              254
      XPNT = NCARSP(I)                                                255
      CALL POINTS(ISRC,DX,DY,DIST,DIST,XPNT)                          256
C
 2360 CONTINUE                                                        257
C
2400  IF (NH + MCARNO.EQ.0) GO TO 2405                                258
      NSRC5 = ISRC                                                    259
      NOIMP = NSRC5                                                   260
C
 2405 IF(NPP .EQ. 0)   GO TO 2555                                     261
C
C     HEATING PLANT EMISSION SOURCES                          00009630
      DO 2500 I=1,NPP                                         00009640262
      ISRC=ISRC+1                                             00009650263
      IF(ISRC.GT.999) GO TO 2550                              00009660264
      XSRC(ISRC)=XPP(I)                                       00009670265
      YSRC(ISRC)=YPP(I)                                       00009680266
      ZSRC(ISRC)=10.0                                         00009690267
      NPUTE(ISRC) = 1                                                 268
      IC=ICPP(I)                                              00009700269
C
      DO 2500 K=1,NPOL                                        00009710270
      KP=KPOL(K)                                              00009720271
 2500 QSRC(ISRC,K)=APP*PPKW(I)*PPEM(IC,KP)                    00009730272
 2550 NSRC6=ISRC                                              00009740273
      NOIMP = NSRC6                                                   274
C
```

```
2555  IF (NFS .EQ. 0)   GO TO 2655                                   275
C
C     FUEL STORAGE EMISSION SOURCES                              00009750
      DO 2600 I=1,NFS                                            00009760276
      ISRC=ISRC+1                                                00009770277
      IF(ISRC.GT.999) GO TO 2650                                 00009780278
      XSRC(ISRC)=XFS(I)                                          00009790279
      YSRC(ISRC)=YFS(I)                                          00009800280
      ZSRC(ISRC)=10.0                                            00009810281
      NPUTE(ISRC) = 1                                                 282
C
      DO 2600 K=1,NPOL                                           00009820283
      KP=KPOL(K)                                                 00009830284
 2600 QSRC(ISRC,K)=FSEM(I,KP)                                    00009840285
C
 2650 NSRC7=ISRC                                                 00009850286
      NCIMP=NSRC7                                                00009860287
C
2655  IF (NS .EQ. 0)   GO TO 3200                                     288
C
C     SURROUNDING EMISSION SOURCES                               00009870
C
      IF (NROLE .EQ. 2)   GO TO 3050                                  289
C
      DO 3000 I=1,NS                                             00009880290
      ISRC=ISRC+1                                                00009890291
      IF(ISRC.GT.999) GO TO 3100                                 00009900292
      XSRC(ISRC)=XQ(I)                                           00009910293
      YSRC(ISRC)=YQ(I)                                           00009920294
      ZSRC(ISRC)=0.5                                             00009930295
      NPUTE(ISRC) = 1                                                 296
      IC=ICQ(I)                                                  00009940297
      DO 3000 K=1,NPOL                                           00009950298
C
      KP=KPOL(K)                                                 00009960299
 3000 QSRC(ISRC,K)=ACTS*AQ(I)*USEM(IC,KP)                        00009970300
      GO TO 3100                                                      301
C
 3050 FH = ACTS                                                       302
```

```
      DO 3060  I = 1,NS                                                  303
      ISRC = ISRC + 1                                                    304
      IF (ISRC .GT. 999)   GO TO 3100                                    305
      XSRC(ISRC) = XQ(I)                                                 306
      YSRC(ISRC) = YQ(I)                                                 307
      ZSRC(ISRC) = 0.5                                                   308
      NPUTE(ISRC) = 1                                                    309
      DO 3058   K = 1,NPOL                                               310
      KP = KPOL(K)                                                       311
 3058 QSRC(ISRC,K) = FH*AQ(I)*VALUEQ(I,KP)                               312
 3060 CONTINUE                                                           313
C
 3100 NSRC8=ISRC                                                 00009980314
C
3200  IF (NUMHIW.EQ.0) GO TO 3300                                        315
C
C     HIGHWAY EMISSION SOURCES                                   00009290
C
      DO 2205  K = 1,NPOL                                                316
 2205 TATEM(K) = 0.                                                      317
C
      THL = 0.                                                           318
      DO 2220  I = 1,NUMHIW                                              319
      FI = CARS(I)*HIWLEN(I)                                             320
      THL = THL + HIWLEN(I)                                              321
C
      DO 2215  K = 1,NPOL                                                322
      KP = KPOL(K)                                                       323
 2215 TATEM(K) = TATEM(K) + FI*ATEM(KP)                                  324
 2220 CONTINUE                                                           325
C
      FH = 1./(ELAT*THL)                                                 326
      DO 2260   I = 1,NUMHIW                                             327
      ISRC = ISRC + 1                                                    328
      IF (ISRC.GT.999) GO TO 3300                                        329
      XSRC(ISRC) = XHIWB(I)                                              330
      YSRC(ISRC) = YHIWB(I)                                              331
      ZSRC(ISRC) = 0.5                                                   332
      NPUTE(ISRC) = 1                                                    333
      DX = XHIWE(I) - XHIWB(I)                                                       334
      DY = YHIWE(I) - YHIW3(I)                                                       335
C
      DO 2250  K = 1,NPOL                                                            336
 2250 QSRC(ISRC,K) = FH*TATEM(K)                                                     337
      DIST = HIWLEN(I)                                                               338
      XPNT = NSPHIW(I)                                                               339
      CALL POINTS(ISRC,DX,DY,DIST,DIST,XPNT)                                         340
C
 2260 CONTINUE                                                                       341
C
      NSRC9 = ISRC                                                                   342
 3300 NSRC = ISRC                                                                    343
C
      IF (NPRINT(16) .EQ. 0)   RETURN                                                344
C     PRINT THE EMISSION RATES                                             00010000
      WRITE (NTAPE,4000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                     345
      NPAGE = NPAGE + 1                                                              346
 4000 FORMAT(1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE , T3)               347
      WRITE (6,4100)                                                       00010030348
 4100 FORMAT (///  44X,44H*** AREAL DISTRIBUTION OF EMISSION RATES ***  00010040349
     1/////7X,19HPOINT OF EMISSION   ,31X,26HEMISSION RATE, GMS PER SEC  00010050
     2///)                                                                 00010060
      WRITE(6,4200)                                                        00010070350
 4200 FORMAT(68X,11HPOLLUTANT  )                                           00010080351
      WRITE(6,4300)                                                        00010090352
 4300 FORMAT(10H NO.  TYPE,3X,7HX-COORD,4X,7HY-COORD,4X,7HZ-COORD  )                353
      WRITE(6,4400) (KPOL(K),K=1,NPOL)                                     00010110354
 4400 FORMAT(38X, 8I11)                                                              355
      II = 1                                                                         356
C
      IF (NSRC1 .EQ. 0)   GO TO 4592                                                 357
      WRITE(6,4500)                                                        00010130358
 4500 FORMAT(///,3X,16HAIRCRAFT SOURCES)                                   00010140359
      WRITE(6,4550)                                                        00010150360
 4550 FORMAT(4X,13H-AT TERMINALS,/)                                        00010160361
      DO 4590 I=1,NSRC1                                                    00010170362
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),                   363
     *    K=1,NPOL)
```

```
4575  FORMAT(1X,I3,I4,2X,11E11.3 )
 4590 CONTINUE
      WRITE (NTAPE, 4591)  NSRC1
 4591 FORMAT (10H  NSRC1 = , I4)
      II = NSRC1+1
C
 4592 IF (NSRC2 .EQ. 0)   GO TO 4600
      WRITE (6, 4500)
      WRITE (6, 4593)
 4593 FORMAT (4X, 17H-DELAY AT RUNWAY, /)
      DO 4594   I = II,NSRC2
      WRITE (6,4575)  I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),
     *   K = 1,NPOL)
 4594 CONTINUE
      WRITE (NTAPE, 4595)  NSRC2
 4595 FORMAT ( 10H  NSRC2 = , I4)
      II = NSRC2 + 1
C
 4600 IF (NSRC3 .EQ. 0)   GO TO 4700
      WRITE(6,4500)
      WRITE(6,4650)
 4650 FORMAT(4X,14H-ALONG RUNWAYS,/)
      DO 4690   I = II,NSRC3
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),
     *    K=1,NPOL)
 4690 CONTINUE
      WRITE (NTAPE, 4691)  NSRC3
 4691 FORMAT ( 10H  NSRC3 = , I4)
      II = NSRC3 + 1
C
 4700 IF (NSRC4 .EQ. 0)   GO TO 4900
      WRITE(6,4500)
      WRITE(6,4750)
 4750 FORMAT(4X,15H-ALONG TAXIWAYS,/)
      DO 4790   I = II,NSRC4
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),
     *    K=1,NPOL)
 4790 CONTINUE
      WRITE (NTAPE, 4791)  NSRC4
 4791 FORMAT (10H  NSRC4 = , I4)                                        337
      II=NSRC4+1                                                00010420398
C
4900  IF (NSRC5 .EQ. 0)   GO TO 5100                                    399
      WRITE(6,5000)                                             00010430400
 5000 FORMAT(///,3X,28HNON-AIRCRAFT AIRPORT SOURCES)            00010440401
      WRITE(6,5050)                                             00010450402
 5050 FORMAT(4X,15H-ALONG HIGHWAYS,/)                           00010460403
      DO 5090 I=II,NSRC5                                        00010740404
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),      405
     *     K=1,NPOL)
 5090 CONTINUE                                                  00010490406
      WRITE (NTAPE, 5091)  NSRC5                                        407
 5091 FORMAT (10H  NSRC5 = , I4)                                        408
      II=NSRC5+1                                                00010500409
C
5100  IF (NSRC6 .EQ. 0)   GO TO 5195                                    410
      WRITE(6,5000)                                             00010510411
      WRITE(6,5150)                                             00010520412
 5150 FORMAT(4X,18H-AT HEATING PLANTS,/)                        00010530413
 5190 CONTINUE                                                  00010560414
      WRITE (NTAPE, 5191)  NSRC6                                        415
 5191 FORMAT (10H  NSRC6 = , I4)                                        416
      II=NSRC6+1                                                00010570417
C
5195  IF (NSRC7 .EQ. 0)   GO TO 5220                                    418
      WRITE(6,5000)                                             00010580419
      WRITE(6,5200)                                             00010590420
 5200 FORMAT(4X,22H-AT FUEL STORAGE AREAS,/)                    00010600421
      DO 5190 I =II,NSRC6                                       00010540422
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),      423
     *     K=1,NPOL)
      DO 5210 I=II,NSRC7                                        00010610424
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),      425
     *     K=1,NPOL)
 5210 CONTINUE                                                          426
      WRITE (NTAPE, 5211)  NSRC7                                        427
 5211 FORMAT (10H  NSRC7 = , I4)                                        428
      II=NSRC7+1                                                00010630429
```

```
C
5220  IF (NSRC8 .EQ. 0)   GO TO 5290
      WRITE(6,5250)                                                        430
 5250 FORMAT(///,3X,19HSURROUNDING SOURCES,/)                      00010640431
      DO 5260   I = II,NSRC8                                       00010650432
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),         433
     *    K=1,NPOL)                                                        434
 5260 CONTINUE
      WRITE (NTAPE, 5261)  NSRC8                                           435
 5261 FORMAT (10H  NSRC8 = , I4)                                           436
      II = NSRC8 + 1                                                       437
C                                                                          438
5290  IF (NSRC9.EQ.0) GO TO 5300
      WRITE(6,5265)                                                        439
5265  FORMAT(///,3X,20HSURROUNDING HIGHWAYS /)                             440
      DO 5295 I=II,NSRC9                                                   441
      WRITE(6,4575) I,NPUTE(I),XSRC(I),YSRC(I),ZSRC(I),(QSRC(I,K),         442
     *    K=1,NPOL)                                                        443
5295  CONTINUE
      WRITE (NTAPE, 5296)  NSRC9                                           444
 5296 FORMAT (10H  NSRC9 = , I4)                                           445
C                                                                          446
5300  CONTINUE
      RETURN                                                               447
      END                                                          00010690448
                                                                   00010700449

 96  COMMENT CARDS        26  CONTINUATION CARDS        97 NUMBERED STATEMENTS
```

```
      SUBROUTINE PRGEN                                                  00001720
C     PRINT THE GENERAL INPUT DATA                                      00001730
C
      COMMON /COM1 / AEM(13,5,4),FOPPS(13,8),USEM(10,8), ATEM(8),
     $   ENP(15),PPEM(8,8),CAACTV(13,8),GAACTV(2,8,12)
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      NTAPE=6                                                           00001760
C
      IF (NPRINT(1) .EQ. 0)  GO TO 5500
      WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
 1000 FORMAT (1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE , I3)
      WRITE(6,1100)                                                     00001790
 1100 FORMAT(///  53X,26H*** GENERAL INPUT DATA ***/// )                00001800
C
      DO 5000  J = 1,5
      GO TO (2001,2002,2003,2004,2005), J
 2000 WRITE(6,3000)                                                     00001840
 3000 FORMAT(46X,39HAPPROACH MODE...EMISSIONS IN MASS UNITS,////)       00001850
      GO TO 4000                                                        00001860
 2001 WRITE (6,3001)
 3001 FORMAT (/// 33X, 37HIDLE MODE...EMISSIONS IN GRAMS/SECOND  ///)
      GO TO 4000
 2002 WRITE (6,3002)
 3002 FORMAT (///  33X, 41HTAKE-OFF MODE...EMISSIONS IN GRAMS/SECOND///)
      GO TO 4000
 2003 WRITE (6,3003)
 3003 FORMAT (///  33X, 42HCLIMB-OUT MODE...EMISSIONS IN GRAMS/SECOND
     *    ///)
      GO TO 4000
 2004 WRITE (6,3004)
 3004 FORMAT (///  33X, 41HAPPROACH MODE...EMISSIONS IN GRAMS/SECOND///)
      GO TO 4000
 2005 WRITE (6,3005)
 3005 FORMAT (///  28X, 54HAPU'S AND SERVICE VEHICLES...EMISSIONS IN GRA
     *MS/SECOND ///)
 4000 WRITE(6,4100)
 4100 FORMAT(14X,9HAIRCRAFT)                                           00002280
      WRITE(6,4200)                                                    00002290
 4200 FORMAT(16X,5HCLASS,43X,9HPOLLUTANT)                              00002300
      WRITE (6,4300) (JJ,JJ = 1,4)                                     00002310
 4300 FORMAT (18X, 4I16///)
      DO 4800   I = 1,15
 4800 WRITE (6,4400)  I, (AEM(I,J,K),K = 1,4)
 4400 FORMAT(17X,I2,3X, 4E16.3 / )
      WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
 5000 CONTINUE
C                                                                      00002490
      IF (NPRINT(2) .NE. 0)  GO TO 5600
 5500 IF (NPRINT(2) .EQ. 0)  GO TO 7010
      WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
 5600 WRITE (NTAPE, 6000)
 6000 FORMAT (//////////14X,104H MASS PER UNIT TIME OF POLLUTANT EMITTED 00002590
     1PER UNIT AREA OF SURROUNDINGS IN A GIVEN CATEGORY, GM/SEC SQ M ///00002600
     2//)                                                              00002610
      WRITE (NTAPE, 6100)  (I, I=1,8)
 6100 FORMAT (10X,12HSURROUNDINGS, 38X,9HPOLLUTANT, / 12X, 8HCATEGORY,
     1  I10, 7I12, ///)
      DO 7000 I=1,10
      WRITE(6,6500)  I,(USEM(I,K),K=1,8)                               00002670
 6500 FORMAT (15X, I2, 5X, 8E12.3 //)                                  00002680
 7000 CONTINUE
 7010 IF (NPRINT(3) .EQ. 0)  GO TO 9010                                00002700
      WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE
      NPAGE = NPAGE + 1
      WRITE(6,7100)                                                    00002720
 7100 FORMAT(///      ,29X,75HMASS OF POLLUTANT EMITTED PER UNIT DISTANC00002730
     1E TRAVELED OF AN AUTOMOBILE, GM/M,//    )                        00002740
      WRITE(6,7200)                                                    00002750
 7200 FORMAT(64X,9HPOLLUTANT)                                          00002760
      WRITE(6,7300)                                                    00002770
 7300 FORMAT(27X,1H1,10X,1H2,10X,1H3,10X,1H4,10X,1H5,10X,1H6,10X,1H7,10X00002780
     1,1H8,///)                                                        00002790
```

```
      WRITE(6,8000)(ATEM(K),K=1,8)                                            00002800 63
 8000 FORMAT(22X,8(E10.3,1X))                                                 00002810 64
      WRITE(6,8100)                                                           00002830 65
 8100 FORMAT (// 23X, 69HPASSENGER AND FLIGHT OPERATIONAL DATA AS A FUNC               66
     *TION OF AIRCRAFT CLASS ////)
      WRITE (NTAFE, 8200)                                                              67
 8200 FORMAT (2X,8HAIRCRAFT,7X,7HAVERAGE,6X,8HAPPROACH,4X,8HTAKE-OFF,4X,               68
     1  9HCLIMB-OUT,5X,7HLANDING,4X,8HTAKE-OFF,4X,7HRATE OF,4X,
     2  7HLANDING,4X,8HTAKE-CFF / 4X,5HCLASS,6X,9HNUMBER OF,6X,
     3  8HVELOCITY,4X,8HVELOCITY,5X,8HVELOCITY,4X,8HDISTANCE,4X,
     4 8HDISTANCE,5X,5HCLIMB,6X,4HTIME,8X,4HTIME / 15X,10HPASSENGERS,
     5  42X,8HTRAVELED,4X,8HTRAVELED / 32X,5HM/SEC,7X,5HM/SEC,7X,
     6  5HM/SEC,7X,6HMETERS,6X,6HMETERS,6X,5HM/SEC,5X,7HSECONDS,5X,
     7  7HSECONDS  ///)
      DO 9000   I = 1,15                                                               69
      WRITE (NTAPE,8600) I,ENP(I),(FOPPS(I,J), J = 1,8)                                70
 8600 FORMAT (5X,I2,10X,F5.0,3X,3(6X,F6.1),6X,F7.0,6X,F6.0,6X,F5.0,                    71
     *  2(6X, F5.0) /)
 9000 CONTINUE                                                                00002970 72
C
 9010 IF (NPRINT(4) .EQ. 0)  RETURN                                                    73
      WRITE (NTAPE, 1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                      74
      NPAGE = NPAGE + 1                                                                75
      WRITE(6,9100)                                                           00002990 76
 9100 FORMAT(////////14X,102HMASS OF POLLUTANT PER UNIT TIME PER FUEL FL00003000 77
    1OW RATE OF AIRPORT HEATING PLANT, GM/SEC PER FUEL FLOW RATE,/////)00003010
      WRITE (NTAPE, 9200)  (I, I = 1,8)                                                78
 9200 FORMAT (14X,4HFUEL, 42X,9HPOLLUTANT, / 14X,4HTYPE,8I12, ///)                     79
      DO 9350 I=1,8                                                           00003070 80
 9350 WRITE (6,9400) I,(PPEM(I,K),K=1,8)                                      00003080 81
 9400 FORMAT (15X,I2, 5X, 8E12.3, //)                                                  82
      RETURN                                                                  00003100 83
      END                                                                     00003110 84

  8  COMMENT CARDS          13  CONTINUATION CARDS         41 NUMBERED STATEMENTS
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```
      SUBROUTINE METEOR(X,Y,XM)                                         00010960  1
C     CALCULATE METEOROLOGICAL PARAMETERS                               00010970
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),           2
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4          TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,          3
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,  00011050
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)
C
      COMMON /COM5/XR,YR,ZR,XS,YS,ZS,RHO,DZM,DZP,ALPHA,ISECT,DX,DY,IRCP 00011070  4
C
      COMMON /COM6/ISS,ISC,HM,ICON,SIGZ,EXPZ,SIGY,EXPY,QS,WINDS,TKI     00011080  5
C
      DIMENSION XSGZLX(7),SIGZLX(7,6),ASGY(6),BSGY(6)                   00011090  6
C
      DATA ELOG10/2.3025851/                                            00011100  7
C
      DATA XSGZLX,SIGZLX/2.,2.30103,2.69897,3.30103,4.,4.69897,5.,      00011110  8
     11.13672,1.46835,2.02119,3.29447,4.77270,6.25093,6.88757,          00011120
     21.02531,1.30750,1.70586,2.36549,3.13354,3.90159,4.23237,          00011130
     30.86332,1.13988,1.50515,2.06446,2.69897,3.33646,3.60206,          00011140
     40.66276,0.92942,1.26951,1.69897,2.13354,2.51587,2.65801,          00011150
     50.54407,0.80277,1.11059,1.52763,1.89763,2.18752,2.26482,          00011160
     60.36173,0.48430,0.92428,1.33244,1.66558,1.89321,1.96848/          00011170
C
      DATA ASGY,BSGY / 0.489, 0.323, 0.211, 0.124, 0.092, 0.063,                  9
     1    0.871, 0.885, 0.895, 0.905, 0.908, 0.909 /
C
      EXLIM = -55.                                                               10
   20 XLOG = ALOG10(X)                                                           11
      CALL LINT(XLOG,7,XSGZLX,SIGZLX(1,ISS),SIGZL)                      00011210 12
      SIGZ = 0.                                                                  13
      EXNU = ELOG10*SIGZL                                                        14
      IF(EXNU .GT. EXLIM)  SIGZ = EXP(EXNU)                                      15
   30 IF (IMPACT .EQ. 1)   GO TO 50                                            16
C
   50 SIGZM=0.47*HM                                                    00011290 17
      IF (SIGZ.GT.SIGZM) GO TO 100                                     00011300 18
      ICON=1                                                           00011310 19
      GO TO 150                                                        00011320 20
  100 SIGZML=ALOG10(SIGZM)                                             00011330 21
      CALL LINT(SIGZML,7,SIGZLX(1,ISS),XSGZLX,XMLOG)                   00011340 22
      XM = 0.                                                                   23
      EXNU = ELOG10*XMLOG                                                       24
      IF (EXNU .GT. EXLIM)   XM = EXP(EXNU)                                     25
      IF (X.GT.2.0*XM) GO TO 200                                       00011360 26
      ICON=2                                                           00011370 27
  150 CONTINUE                                                         00011380 28
      ETEM = 0.                                                                 29
      ETEP = 0.                                                                 30
      TEM=-0.5*(DZM/SIGZ)**2                                           00011390 31
      IF (TEM .GT. EXLIM)   ETEM = EXP(TEM)                                     32
      TEP=-0.5*(DZP/SIGZ)**2                                           00011410 33
      IF (TEP .GT. EXLIM)   ETEP = EXP(TEP)                                     34
      EXPZ=ETEM+ETEP                                                   00011430 35
      GO TO 250                                                        00011440 36
  200 ICON=3                                                           00011450 37
  250 IF (IMPACT.NE.1) RETURN                                          00011460 38
C
      SIGY=ASGY(ISS)*X**BSGY(ISS)                                      00011470 39
      EXNU = -0.5*(Y/SIGY)**2                                                   40
      EXPY = 0.                                                                 41
      IF (EXNU .GT. EXLIM)   EXPY = EXP(EXNU)                                   42
      RETURN                                                           00011490 43
      END                                                              00011500 44

   12  COMMENT CARDS        14  CONTINUATION CARDS        7 NUMBERED STATEMENTS
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* * *   S O U R C E   P R O G R A M   L I S T I N G   09/17/74   * * *   PAGE  52
      SUBROUTINE LINT(X,NTA3,XTAB,YTAB,Y)                                00011510   1
C     LINEAR INTERPOLATION OF A FUNCTION OF ONE VARIABLE                 00011520
C
      DIMENSION XTAB(1),YTAB(1)                                          00011530   2
C
C     CHECK IF THERE IS ONLY ONE TABULAR ENTRY                           00011540
      IF (NTAB.NE.1) GO TO 50                                            00011550   3
C
      Y=YTAB(1)                                                          00011560   4
      RETURN                                                             00011570   5
C
C     FIND THE TABULAR ENTRIES BETWEEN WHICH X LIES                      00011580
   50 DO 100 N=2,NTAB                                                    00011590   6
      IF (X.GT.XTA3(N)) GO TO 100                                        00011600   7
      N2=N                                                               00011610   8
      GO TO 200                                                          00011620   9
  100 CONTINUE                                                           00011630  10
C
      N2=NTAB                                                            00011640  11
  200 N1=N2-1                                                            00011650  12
C
C     CALCULATE Y ASSUMING Y=A+B*X                                       00011660
      B=(YTAB(N2)-YTAB(N1))/(XTAB(N2)-XTAB(N1))                          00011670  13
      A=YTAB(N1)-B*XTAB(N1)                                              00011680  14
      Y=A+B*X                                                            00011690  15
      RETURN                                                             00011700  16
      END                                                                00011710  17

  10  COMMENT CARDS          0  CONTINUATION CARDS          3 NUMBERED STATEMENTS
```

```
      SUBROUTINE PRCON                                                  00012080  1
C     PRINT THE CONCENTRATION OUTPUT                                    00012090
C
      COMMON /COM3/ELAT,ACTVTY(13),APP,ACTS,IPOL(8),IWRITE,IMPACT,TIDLE,                2
     1NRCP,XRCP(50),YRCP(50),ZRCP(50),ITP,HMIX,KWS,KS,NWD,WD,PW,IFREQ,
     2FREQ(6,16,6),FTR(10,2),COMENT(18),POLLUT(6,8)
C
      COMMON /COM4/NPOL,KPOL(8),AIMP(8),OIMP(8),SIMP(8),TAEM(10,8),     00012100  3
     1TATEM(8),NSRC,XSRC(999),YSRC(999),ZSRC(999),QSRC(999,8),NPUTE(999)
     2,NAIMP,NOIMP,NSRC1,NSRC2,NSRC3,NSRC4,NSRC5,NSRC6,NSRC7,NSRC8,NSRC9
     3,RUNIMP(8),TAXIMP(8),RODIMP(8),HIMP(8),DLYIMP(8),POTION(10,8),
     4  SERVEH(2,8)
C
      COMMON /COM5/XR,YR,ZR,XS,YS,ZS,RHO,DZM,DZP,ALPHA,ISECT,DX,DY,IRCP 00012130  4
C
      COMMON /COM7/ HEADER(20),NPAGE,NYEAR,MONTH,NDAY,NHOUR,MIN,NSEC,                   5
     1  NOBTIM,NPRINT(20),JULIAN,ITIME
C
      DIMENSION  DETAL(8)                                                               6
C
      NTAPE=6                                                           00012140  7
C
      IF (NPRINT(17) .EQ. 0)  GO TO 2000                                                8
C
      IF(IRCP.NE.1) GO TO 1060                                          00012150  9
      WRITE (NTAPE,1000) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE                       10
      NPAGE = NPAGE + 1                                                                11
 1000 FORMAT(1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE ,I3 //                12
     1  53X, 28H*** CONCENTRATION OUTPUT ***)
      GO TO 55                                                                         13
 1060 IF (MOD(IRCP,2)) 50,55,50                                                        14
   50 WRITE (NTAPE,1100) HEADER,NHOUR,MIN,NDAY,MONTH,NYEAR,NPAGE,IRCP,                 15
     1   XR,YR,ZR
 1100 FORMAT(1H1,20A4,9H  RUN AT ,I2,1H.,I2,I4,1X,A4,I6,7H  PAGE ,I3 //                16
     1             35X,18HRECEPTOR POINT NO.,I3,5H (X= ,E9.3,7H M, Y= ,
     2E9.3,7H M, Z= ,E9.3,3H M)  /)
      NPAGE = NPAGE + 1                                                                17
      WRITE (NTAPE, 1110)  COMENT                                                      18
      GO TO 60                                                                         19
   55 WRITE (6,1105) IRCP,XR,YR,ZR
 1105 FORMAT( /// 35X,18HRECEPTOR POINT NO.,I3,5H (X= ,E9.3,7H M, Y= ,
     1E9.3,7H M, Z= ,E9.3,3H M)  /)
      WRITE (NTAPE, 1110)  COMENT
 1110 FORMAT (45X, 18A4)
   60 WRITE (6,1200)
 1200 FORMAT(47X,50HAVERAGE CONCENTRATION IN TIME PERIOD, GMS PER CU M/)00012250
      WRITE (6,1300)                                                    00012270
 1300 FORMAT(41X,9HPOLLUTANT,23X,6HSOURCE,/)                            00012280
      WRITE (6,1400)                                                    00012290
 1400 FORMAT(56X,8HAIRCRAFT,7X,12HNON-AIRCRAFT,5X,12HSURROUNDINGS, 9X,
     1  5HTOTAL  )
      WRITE (6,1500)                                                    00012310
 1500 FORMAT (73X,7HAIRPORT/)                                           00012320
C
      DO 1900 K=1,NPOL                                                  00012330
      SUM =AIMP(K)+RUNIMP(K)+TAXIMP(K)+RODIMP(K)+OIMP(K)+SIMP(K)+HIMP(K)
      WRITE (NTAPE, 1600)  KPOL(K),AIMP(K),OIMP(K),SIMP(K),SUM
 1600 FORMAT (45X,I2,1X, 3(6X,E11.4) , 6X, E12.5, /)
 1900 CONTINUE                                                          00012360
C
 2000 IF (NPRINT(18) .EQ. 0)  RETURN
C
      WRITE (9) JULIAN,ITIME,IRCP,XR,YR,ZR,NHOUR,NDAY,MONTH,NYEAR
      DO 2100   K = 1,NPOL
      SUM =AIMP(K)+RUNIMP(K)+TAXIMP(K)+RODIMP(K)+OIMP(K)+SIMP(K)+HIMP(K)
      WRITE (9)  KPOL(K), AIMP(K), RUNIMP(K), TAXIMP(K), RODIMP(K),
     *  OIMP(K), SIMP(K), HIMP(K), SUM
 2100 CONTINUE
C
      WRITE (11)  JULIAN,ITIME,IRCP,XR,YR,ZR,NHOUR,NDAY,MONTH,NYEAR
      DO 2200   K = 1,NPOL
      DO 2110   I = 1,4
 2110 DETAL(I) = AIMP(K)*POTION(I,K)
      DO 2115   I = 5,6
 2115 DETAL(I) = TAXIMP(K)*POTION(I,K)
      DETAL(7) = DLYIMP(K)
      DETAL(8) = 0.
      DO 2120   I = 1,7
 2120 DETAL(8) = DETAL(8) + DETAL(I)                                                  52
      WRITE (11)  KPOL(K), (DETAL(I), I = 1,8)                                        53
 2200 CONTINUE                                                                        54
C
      RETURN                                                                  00012370 55
      END                                                                     00012380 56

 14  COMMENT CARDS        14  CONTINUATION CARDS        20 NUMBERED STATEMENTS
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```
      SUBROUTINE POINTS(I, DXA, DYA, DIST, TOTAL, XPNT)
C
C  THIS SUBROUTINE COMPUTES THE NECESSARY POINTS TO APPROXIMATE A LINE
C     SOURCE FOR THE AREAL SUBROUTINE.
C
      COMMON /COM2/IAPT,ANAME(3),NS,NT,NH,NR,NX,NG,NPP,NFS,IUR,ICQ(99),
     1AQ(99),XQ(99),YQ(99),XT(12),YT(12),FTT(12),XHB(12),YHB(12),XHE(12)
     2,YHE(12),NHSP(12),AUTOT,FAPP,RUNWAY(10,6),TAXIWA(12,10,6),
     3NRSP(12),NRAP(12),NRQP(12),NXSP(12),
     4          TAXIT,XG(12),YG(12),FTG(12),XPP(12),YPP(12),PPKW(12),
     5ICPP(12),ADIST,CDIST,XFS(12),YFS(12),FSEM(12,8),VALUEQ(99,4),NROLE
C
      COMMON /COM4/NPOL,KPOL(8),AIMP(8),OIMP(8),SIMP(8),TAEM(10,8),
     1TAESM(8),NSRC,XSRC(999),YSRC(999),ZSRC(999),QSRC(999,8),NPUTE(999)
     2,NAIMP,NOIMP,NSRC1,NSRC2,NSRC3,NSRC4,NSRC5,NSRC6,NSRC7,NSRC8,NSRC9
     3,RUNIMP(8),TAXIMP(8),RODIMP(8),HIMP(8),DLYIMP(8),POTION(10,8),
     4  SERVEH(2,8)
C
      DELTA = DIST/XPNT
      NPNT = XPNT
      DX = DXA*DELTA/TOTAL
      DY = DYA*DELTA/TOTAL
C
      XSRC(I) = XSRC(I) + DX/2.
      YSRC(I) = YSRC(I) + DY/2.
C
      DO 10   K = 1,NPOL
 10   QSRC(I,K) = QSRC(I,K)*DELTA
C
      M = I
      DO 20   J = 2,NPNT
      I = I + 1
      XSRC(I) = XSRC(M) + DX
      YSRC(I) = YSRC(M) + DY
      ZSRC(I) = ZSRC(M)
      NPUTE(I) = NPUTE(M)
      DO 18   K = 1,NPOL
 18   QSRC(I,K) = QSRC(M,K)
      M = I
 4    FORMAT(18I4)
      READ (ITAPE,5)  NSTA, NPOLUT
 5    FORMAT (24I3)
C
      DO 300   K = 1,NRECPT
      N = 0
C
      DO 400   I = 1,NDAYS
      DO 300   J = 1,NTMPRD
      N = N + 1
C
 40   READ (NDATA) JULIAN(N), ITIME(N), IRCP
      IF (K - IRCP)  40,50,40
C
 50   DO 100   L = 1,NPOL
      READ (NDATA) KPOL, (VAL(I,J,1,L,M), M = 1,3)
      IF (KPOL .EQ. NPOLUT(L))   GO TO 100
      WRITE (6, 1115)  I,J,K,L
1115  FORMAT('0THE POLLUTANT CARD IS MISSING FOR ', 4I8)
      GO TO 200
100   CONTINUE
200   CONTINUE
300   CONTINUE
400   CONTINUE
C
      DO 800   L = 1,NPOL
      KAY = NPOLUT(L)
C
      WRITE (NTAPE, 1710) HEADER,NSTA(K),(POLLUT(II,KAY),II=1,6), NPAGE,
     *   ((TYPE(II,JJ), II = 1,3), JJ = 1,3)
 1710 FORMAT(1H1,15X,20A4 // 10X,'FROM RECEPTOR NUMBER ',I2,'  AND POLLU
     $TANT ',6A4, 40X,'PAGE  ',I3  /// 12X, 8(3X, 3A4) //)
      NPAGE = NPAGE + 1
      N = 0
      NGOOD = 0
C
      DO 600   I = 1,NDAYS
      DO 500   J = 1,NTMPRD
      N = N + 1
```

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```
      IF (VAL(I,J,1,L,8) .LT. 1.0E-09)   GO TO 490
      WRITE (6,1510) JULIAN(N),ITIME(N), (VAL(I,J,1,L,M), M = 1,8)
 1510 FORMAT (1H0, I5, I8, E13.4, 7E15.4)
 490  XX = VAL(I,J,1,L,8)
      IF (XX .GE. 1.0E-03)   NGOOD = NGOOD + 1
      ARRAY(N) = XX*FACTOR(KAY)
500   CONTINUE
600   CONTINUE
C
      IF (NGOOD)  700,700,625
 625  NUM = N
      CALL MISR(NUM,1,ARRAY,CODE,XBAR,STD,SKEW,CURT,R,NXM,A,B,S,IER)
C
      WRITE (6,30) NSTA(K),(POLLUT(II,KAY),II=1,6),(TYPE(II,8),II=1,3),
     $  XBAR(1),STD(1),SKEW(1),CURT(1),IER
C
30    FORMAT(1H0 / 1H0 'THE FOLLOWING STATISTICS ARE FOR RECEPTOR  NUMBE
     1R ',I2,'  AND POLLUTANT ',6A4,'FOR THE ', 3A4,
     2 /// 10X,'MEAN = ',F12.4// 10X,'STANDARD DEVIATION = ',F12.4// 10X
     3  ,'SKEWNESS = ',F12.4// 10X,'KURTOSIS = ',F12.4// 10X,'ERROR =  '
     4  , I2 ///)
C
      CALL PERC(ARRAY,NUM,PCTILE,X)
C
      WRITE (6,25) (I,I=5,50,5),(PCTILE(I),I=1,12),(I,I=55,95,5),
     * (PCTILE(I),I=13,24),X(NUM),X(1), NUM
C
25    FORMAT ('0THE PERCENTILE VALUES ARE:' // 5X,'1%',9X,'2 ',10('%',8X,
     1  I2),'%'/ 1H ,F10.2,11F11.2 //// 4X, 9(I2,'%',8X),'97%',8X,'98%',
     2  8X,'99%' / 1H ,F10.2,11F11.2 ///// 10X,'WITH THE LOWEST VALUE OF
     3 ',F15.2,'  AND THE HIGHEST VALUE OF ',F15.2,'   OUT OF  ',I6,
     4  ' VALUES.' )
C
 640  DO 675   M = 1,7
      N = 0
      NGOOD = 0
      DO 650   J = 1,NTMPRD
      DO 650   I = 1,NDAYS
      N = N + 1
```

```
            XX = VAL(I,J,K,L,M)                                                  71
            IF (XX .GE. 1.0E-09)   NGOOD = NGOOD + 1                             72
            ARRAY(N) = XX*FACTOR(KAY)                                            73
      650   CONTINUE                                                             74
     C
            IF (NGOOD)  675,675,660                                              75
      660   NUM = N                                                              76
     C
            CALL MISR(NUM,1,ARRAY,CODE,XBAR,STD,SKEW,CURT,R,NXM,A,B,S,IER)       77
     C
            WRITE(6,30) NSTA(K),(POLLUT(II,KAY),II=1,6),(TYPE(II,M),II=1,3),     78
           $  XBAR(1),STD(1),SKEW(1),CURT(1),IER
     C
            CALL PERC(ARRAY,NUM,PCTILE,X)                                        79
     C
            WRITE (6,25) (I,I=5,50,5),(PCTILE(I),I=1,12),(I,I=55,95,5),          80
           * (PCTILE(I),I=13,24),X(NUM),X(1), NUM
     C
      675   CONTINUE                                                             81
     700    CONTINUE                                                             82
     C
     800    CONTINUE                                                             83
     C
            REWIND NDATA                                                         84
      900   CONTINUE                                                             85
     1000   CONTINUE                                                             86
     C
            STOP                                                                 87
            END                                                                  88

      33  COMMENT CARDS        25  CONTINUATION CARDS        26 NUMBERED STATEMENTS
```

IN